

COLLEGE OF ENGINEERING

THE SCHOOL OF CIVIL ENGINEERING

THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING

THE SCHOOL OF ELECTRICAL ENGINEERING

THE SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING

THE DEPARTMENT OF ENGINEERING PHYSICS

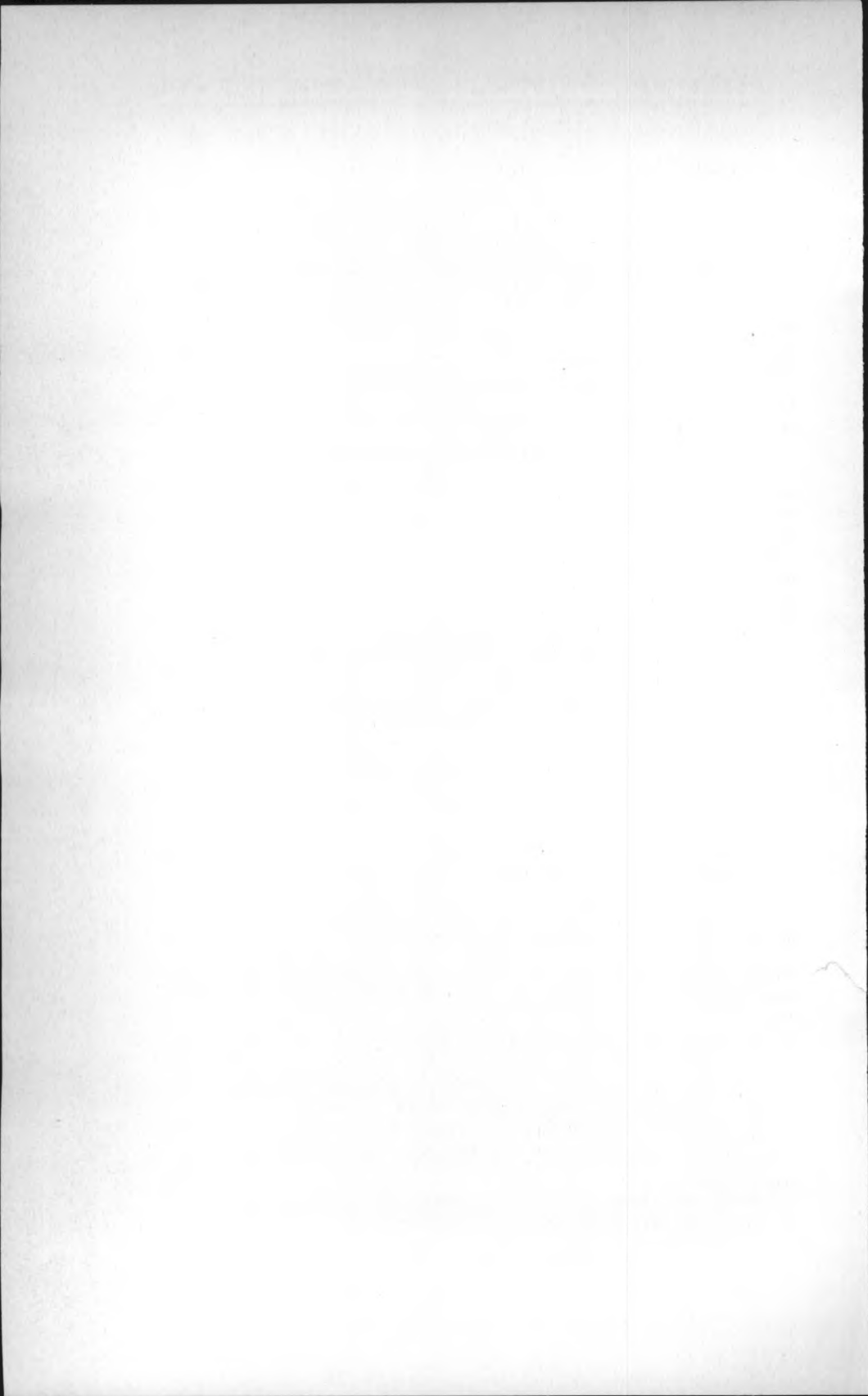
AGRICULTURAL ENGINEERING

THE GRADUATE SCHOOL OF AERONAUTICAL ENGINEERING

1958-1959

CORNELL UNIVERSITY ANNOUNCEMENTS

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CORNELL UNIVERSITY ANNOUNCEMENTS

Supplement to Volume 49, Number 6, September 10, 1957

COLLEGE OF ENGINEERING, 1958-1959 SIBLEY SCHOOL OF MECHANICAL ENGINEERING

COURSES IN MATERIALS PROCESSING

Messrs. CARPENTER, CRISSEY, DISPENZA, GEER, HUSON, and MORGAN

3402. *MACHINE TOOLS*. Credit 2 hrs. Both terms. 1 Lect. 1 Lab. Lectures, demonstrations, and laboratory practice on basic machine tools and their accessories; project layout and operation sequence exercises for unit making of goods; demonstrations of production tooling and gaging.

3403. *FUNDAMENTALS OF MACHINE TOOLS*. Credit 1 hr. Both terms. 1 Lect. 1 Lab. Demonstrations and practice on basic machine tools and their accessories; use of unit measuring instruments.

3404. *PRODUCTION MACHINE TOOLS*. Credit 2 hrs. Both terms. 1 Lect. 1 Lab. Prereq., 3406, 3262. Lectures, demonstration studies, and analyses of machine tools for quantity production of goods; jigs, fixtures, and other tooling accessories are investigated; operation analysis and quality limitations are discussed and demonstrated.

3405. *GAGE LABORATORY*. Credit 1 hr. Both terms. 1 Lab. Demonstration studies of measuring devices and techniques for control of size, form, and alignment of commercial goods to A.S.A. and other standards; laboratory practice in inspection methods; quality control data studies; calibration and gage checking.

3406. *MACHINE TOOL TECHNOLOGY*. Credit 2 hrs. Both terms. 1 Lect. 1 Lab. Study of chip formation, cutting tools and fluids, speeds and feeds, and their relations to machinability; analyses of general purpose machines and their accessories; machining practice including layouts, set-ups, and use of measuring instruments.

3407. *ADVANCED MATERIALS PROCESSING*. Credit and hours as arranged with department. Special work in selected areas of mechanical technology; topics and extent of study assigned to suit individual or group needs.

3411. *CUTTING TOOLS*. Credit 3 hrs. Both terms. 2 Lect. 1 Lab. Prereq., 3404, 1152, 1231. Physics of chip formation; tool life, Woxen's and Ernst-Merchant equations; machinability factors; tool preparation; cutting fluid performance; work-tool relations.

3412. *MACHINE TOOL OPERATIONS*. Credit 3 hrs. Both terms. 2 Lect. 1 Lab. Prereq., 3404, 3262, 3405. An advanced and detailed study of production machinery and tooling; operation sequence; fixture and cutter selection; transfer schemes; special machinery; quality limitations.

3413. *MACHINE TOOL ANALYSIS*. Credit 3 hrs. Both terms. 1 Lect. 2 Labs. Prereq., 3404, 3262, 3351. An intensive investigation of machine tool capacities, standard tooling and dimensions of elements; analysis of power drives, speeds and feeds; performance studies; vibration and rigidity problems; maintenance and lubrication; machine tool manufacture; industrial needs and development trends.

3425. *ADVANCED GAGE LABORATORY*. Credit 3 hrs. Both terms. 1 Lect. 2 Labs. Prereq., 3405, 1222, 3241. Intensive study of gaging principles and practices; quality control applications; continuous gaging and automatic sorting; selective assembly; noncontact and nondimensional inspection; machine tool inspection standards.

3498, 3499. *PROJECT*. Total credit 6 hrs. Hours of credit for each course will depend upon the amount and quality of work done each term. Work of the 9th and 10th terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of materials processing.

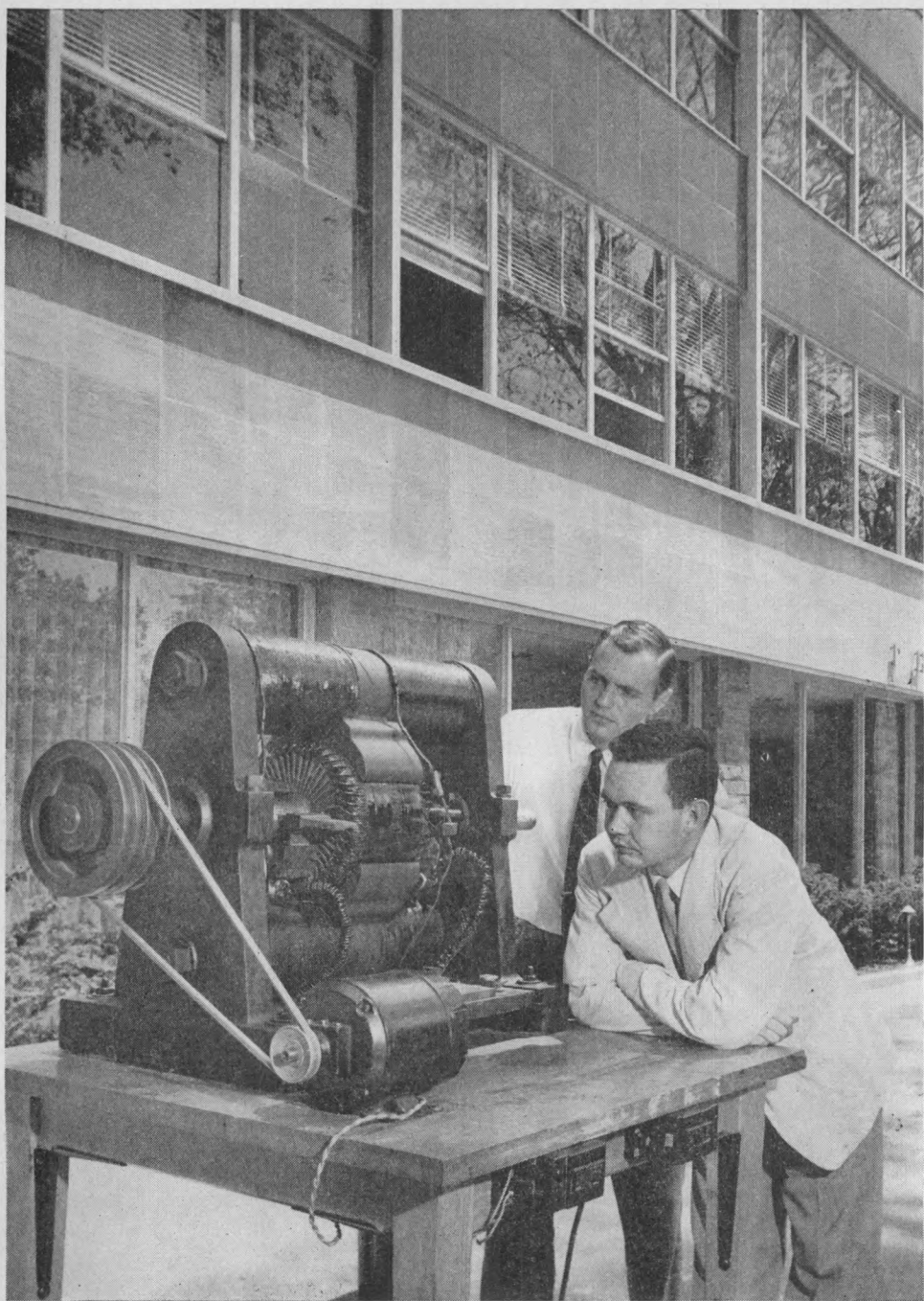


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THE OLD AND THE NEW: MORE THAN SEVENTY-FIVE YEARS
OF CORNELL ENGINEERING

Shown at the entrance of Phillips Hall of electrical engineering (1955) is the historic dynamo that gave the Cornell campus outdoor electric lights in 1878, the first such permanent lighting system in America.

COLLEGE OF ENGINEERING

ORGANIZATION AND HISTORY

THERE ARE two principal types of engineering colleges in America today. One is a self-contained unit stressing science and technology, often referred to as a technological institute. The other, of which the College of Engineering at Cornell is an example, is that subdivision of a university which emphasizes technological education but, in the development of its curricula, is able to call upon the educational resources of other programs of professional and nonprofessional study. At Cornell these other areas of study include agriculture, architecture, arts and sciences, business and public administration, home economics, hotel administration, industrial and labor relations, and law.

Engineering has had an important place in the program of Cornell University from the beginning. The Federal Land Grant, or Morrill Act, of 1862, which supplied a considerable proportion of the University's original endowment, specified that a leading object of the institution should be to teach "such branches of learning as are related to . . . the mechanic arts"; and this provision was in perfect accord with the ideals of the founder and of the first president. Both Ezra Cornell, the practical man of affairs who had amassed a fortune in the Western Union Telegraph Company, and Andrew D. White, the brilliant scholar and educator who had carefully analyzed contemporary higher education in America and in Europe, believed in the equal dignity of scientific and classical studies and determined to put the practical arts, such as engineering, on the same plane with the humanities. This program was considered revolutionary when announced at the University's opening in 1868. That it has since been generally adopted by American universities indicates the soundness of the basic Cornell idea that instruction in engineering should be given on a high professional level. The College of Engineering still adheres firmly to this policy.

Mechanical engineering and civil engineering have been strong divisions of the University since its foundation. In 1883 Cornell opened courses in electrical engineering, among the first to be offered anywhere in America; and in 1919, when the Board of Trustees formed the present College of Engineering, the School of Electrical Engineering was established. Courses in Chemical Engineering were organized in 1931, and seven years later the School of Chemical Engineering was established to supervise the curriculum which leads to the degree of

Bachelor of Chemical Engineering. A course in metallurgical engineering has now been added, and the name of the school has been changed to the School of Chemical and Metallurgical Engineering. In 1946 the Graduate School of Aeronautical Engineering was founded. The same year the Department of Engineering Physics was started. Finally, in 1952, a professional curriculum in agricultural engineering was established as a joint program with the College of Agriculture.

CURRICULA AND DEGREES

UNDERGRADUATE STUDY is available in these divisions of the College: The School of Civil Engineering, the Sibley School of Mechanical Engineering, the School of Electrical Engineering, the School of Chemical and Metallurgical Engineering, and the Department of Engineering Physics. A course in professional agricultural engineering is given in cooperation with the College of Agriculture.

GRADUATE STUDY is available in the Engineering Division of the Graduate School of the University (including the schools and departments listed above and the Department of Mechanics and Materials) and in the Graduate School of Aeronautical Engineering.

Cornell University confers the following degrees on the successful completion of undergraduate courses of study in the College of Engineering: Bachelor of Civil Engineering (B.C.E.); Bachelor of Mechanical Engineering (B.M.E.); Bachelor of Electrical Engineering (B.E.E.); Bachelor of Chemical Engineering (B.Ch.E.); Bachelor of Metallurgical Engineering (B.Met.E.); Bachelor of Engineering Physics (B.Eng.Phys.); Bachelor of Agricultural Engineering (B.Agr.E.).

The general degrees of Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) are available in all the various divisions of engineering and in related fields in the physical sciences. These degrees require advanced work in major and minor subjects, as well as the completion of individual research. They are granted by the University on the recommendation of the faculty of the Graduate School. In addition, the following professional graduate degrees are available: Master of Chemical Engineering (M.Ch.E.), Master of Civil Engineering (M.C.E.), Master of Electrical Engineering (M.E.E.), Master of Industrial Engineering (M.I.E.), Master of Mechanical Engineering (M.M.E.), and Master of Metallurgical Engineering (M.Met.E.). These degrees are administered by the Engineering Division of the Graduate School and are awarded on the recommendation of the faculty of the Graduate School upon the completion of specific curricula in the various schools of the College of Engineering.

The degree of Master of Aeronautical Engineering (M.Aero.E.) is granted on the recommendation of the faculty of the Graduate School of Aeronautical Engineering.

OBJECTIVES

An engineering career has its roots in science and technology, but in its breadth it touches many areas of human activity. The purpose of Cornell engineering and of Cornell life is to create a balanced experience that will serve the engineer in the full range of his future progress. In his studies the Cornell engineer builds a broad foundation of fundamentals in the basic sciences, in basic engineering applications, and in modern technology, much of which is given substance in extensive laboratory practice. He follows a major branch of engineering, avoiding the limitations imposed on future development by narrow specialization—in fact, he studies fundamentals in the adjacent areas of engineering in anticipation of a wide scope of future activities. This broad basic approach has enabled a considerable number of Cornell engineers to develop opportunities outside their original fields of study and experience and to gain distinction in complex enterprises requiring the coordination of many and varied activities.

The further development of this kind of background is supported by the inclusion of a solid core of liberal, general, and managerial studies throughout the period of his technical studies. By including the equivalent of a full year's work in these studies in the five years of engineering training, the young engineer achieves a broadened philosophy and understanding as a natural part of his professional background.

Formal academic work occupies a substantial part of each student's time; nevertheless, it is only a part. Beyond this are the opportunities of university life that form a distinctive influence in personal development and that should be a primary objective in the plan of each student for a collegiate experience of maximum effectiveness. We are particularly happy that the Cornell engineer can study and live in an atmosphere that is not only of strong engineering aspect but that is charged as well with the vitality of a University community dedicated to scholarship in the whole range of human endeavor. He carries with him, therefore, not only the components of his own learning, but also the intellectual stimulation of his association with the University community and the spiritual influence of the University's natural setting. Much of the Cornell tradition has been shaped of these factors; much of the purpose of Cornell engineering gains substance through their effect.

It is our aim to make available to the students who have shown the aptitude, character, and high determination for engineering study at Cornell all of the elements of knowledge, experience, and inspiration that will make for notable achievement in a long professional career.

THE CORNELL FIVE-YEAR PROGRAM

Cornell requires five years for the completion of undergraduate study in the branches of engineering for which it offers degrees. This

departure from the traditional four-year curricula results from the conviction that in no shorter time can a sound and adequate technological training and the necessary acquaintance with the liberal arts be achieved.

Engineering problems grow more difficult and complex, and engineering technology continues to expand. At the close of World War I, we were still using Model T Fords; airplanes were still called "crates"; there was no transcontinental air service for passengers, mail, or express; radio was in its infancy, and there was no television; there were no high-speed diesel locomotives; and many of the developments that came about during World War II were not even dreamed about, such as radar, UHF and VHF communication, guided planes and missiles.

It is true that a considerable amount of engineering work can be done successfully today with the training that was provided twenty-five years ago. On the other hand, if the engineers of the next quarter-century are to be able to cope with the maintenance and advancement of the expanding technological system that characterizes the world today, they must surely be better trained in mathematics and the basic sciences. Equally important for the engineer of today and tomorrow is the need for greater acquaintance with the social sciences and the humanities, which will help prepare him for his role as citizen and for leadership in a complex society.

These requirements of engineering education cannot be met by further compressing the already crowded curricula of yesterday. As law and medicine achieved professional maturity, they of necessity expanded, and continued to expand, their training programs. Engineering must do likewise.

Some engineering colleges have tried to meet this challenge by arranging combination courses in cooperation with liberal arts colleges which provide for three years in a liberal arts college followed by two years of technological training in an engineering college. This expedient highlights the fundamental distinction between the independent liberal arts college and the independent technical school, on the one hand, and, on the other, a university community in which one finds several diverse fields of undergraduate study. Engineering education today demands a bringing together into one integrated program of instruction both technical and nontechnical subjects.

At Cornell, the blending of liberal arts and engineering is accomplished at all levels of instruction in such a manner as to take full advantage of the proper sequences of courses, and this is possible because Cornell is able to provide, on one campus, educational opportunities in both fields. The Cornell engineering student acquires an early acquaintance with engineering. He also is able to obtain part of his preparation in liberal arts in the later years of his program when

added maturity and a broader base of knowledge make certain subjects more meaningful to him.

The "three and two" combination curricula offered by some institutions are an approximation of this integrated program of arts and engineering, limited primarily by geographical separation and the difficulties inherent therein.

The Cornell engineering curricula are composed of four principal categories of subjects:

- (1) Basic science (mathematics, physics, chemistry).
- (2) Applied engineering science (mechanics, properties of materials, thermodynamics, electrical theory, etc.)
- (3) Applied technology (structural design, hydraulics, industrial engineering, electronics, power, chemical operations, and similar subjects related to modern engineering practice).
- (4) General, managerial, and liberal studies (English, history, management, psychology, public speaking, economics, law, and such additional subjects in the several divisions of the University as the student may elect).

The distribution of courses from these categories varies with each curriculum, but in general the basic science and applied engineering science are presented in the first half and applied technology in the latter half. The nonscientific, nontechnological subjects are to be found throughout the five years.

The courses in liberal arts or other nontechnical fields which each student is either required or may elect to study comprise about one-fifth of each curriculum. In some curricula the majority of such courses is prescribed; in others the majority is elective. In all of them a student will spend the equivalent of about one year of his five on subjects outside the fields of engineering, mathematics, and science.

ADMISSION

PROCEDURE AND REQUIREMENTS

All correspondence concerning admission to the College of Engineering should be addressed to the Director of Admissions, Edmund Ezra Day Hall, Cornell University, Ithaca, New York, who will forward the necessary application blanks on request.

Detailed information concerning the requirements for admission and methods of procedure are outlined in the University's *General Information Announcement*, which every candidate for admission should read carefully and which can be obtained by writing to the Cornell University Announcements Office.

Entrance subjects must include English (four units), elementary and intermediate algebra (two units), plane geometry (one unit), and trigonometry (one-half unit). A foreign language (two units) or history (two

units); advanced algebra (one-half unit) *or* solid geometry (one-half unit); and chemistry (one unit) *or* physics (one unit) must also be offered. It is strongly recommended that at least three of the elective units offered to make up the balance of sixteen be in language or history. Applicants are also advised to offer advanced algebra rather than solid geometry, when a choice is possible. Candidates for admission to the School of Chemical and Metallurgical Engineering are required to have chemistry (one unit).

Each candidate for admission is required to take the Scholastic Aptitude Test of the College Entrance Examination Board and to request the Board to report the results to the Director of Admissions, Cornell University. Candidates are urged to take the test in January of their senior year.

The number of applicants admitted to the several schools of the College of Engineering is limited by the facilities available for adequate instruction. The committees on admissions in each of the Schools will exercise discretionary power in selecting those to be admitted. Preference will be given to those candidates whose academic preparation and personal character indicate fitness to pursue with success the course of study to be undertaken, who show evidence of professional promise, and who complete the filing of their entrance credentials in ample time for the committee to give thorough consideration to their qualifications.

CHOICE OF CURRICULUM

Every applicant for admission is asked to designate the branch of engineering he wishes to study, namely, civil engineering, mechanical engineering, electrical engineering, chemical engineering, metallurgical engineering, or engineering physics. Each branch has its own curriculum which carries its own professional degree.

The first year of study is essentially the same for all branches and includes mathematics, physics, chemistry, English, and appropriate courses in descriptive geometry or drafting. This similarity of the curricula in the freshman year makes it possible for students to transfer from one division to another of the College without great hindrance when for one reason or another a change of objective is desirable. Thus, no applicant in his first year need feel that by committing himself to a particular branch of engineering education he has made an irrevocable decision.

After the second year, as the several curricula begin to diversify, transfer within the College of Engineering is somewhat more difficult and in a few instances may necessitate an additional term or more of study.

Applications for transfer should be made to the Director of the prospective school during the term preceding the one in which the student wishes to change his course, and students should realize that the earlier

such transfers are made the fewer will be the resulting complications of curricular adjustment.

SPECIAL PROGRAMS OF STUDY

THE INDUSTRIAL COOPERATIVE PROGRAM

During the fourth term of the regular curriculum students in electrical and mechanical engineering who are in good standing may apply for admission to the Industrial Cooperative Program.

The Cooperative Program provides three work periods of term length (about 16 weeks each) in one of the following industries operating the plan with the University: American Gas and Electric Service Corporation, Air Reduction Company, Combustion Engineering, Inc., Cornell Aeronautical Laboratory, General Electric Company, International Business Machines Corporation, Philco Corporation, Procter and Gamble, and Stromberg-Carlson Company (a division of General Dynamics Corporation).

By utilizing the three summer periods after the fourth term (normally vacation periods), Cooperative students are enabled to complete all the academic work regularly required for the Bachelor's degree and can graduate with their regular classes. The schedule is as follows after Term 4:

<i>Period</i>	<i>Term</i>	<i>Term</i>	<i>Term</i>
Summer	5	Industry	8
Fall	Industry	7	9
Spring	6	Industry	10

It is to be noted that the Cooperative student remains with his regular classmates during all terms on campus except the fifth and eighth, which he takes in the summer. The Cooperative Program therefore is not an accelerated program and involves a minimum of departure from the regular program.

Although the student is on the industry payroll during the work periods, the function of the plan is educational rather than to provide part-time employment. The work in industry is coordinated with the student's studies so far as practicable and provides an invaluable opportunity for him to direct his study interests on campus toward the realities of his future environment. Supervision is provided for each student, both from campus and industry, to ensure his obtaining optimum benefit from the Program. Many students have found this a profound influence on their objectives and on their progress both before and after graduation.

Applications for the Cooperative Program are accepted in the fourth term only. Applicants are subject to approval both by the College and

by one of the cooperating industries. Admission to the plan involves no obligation on the part of either the student or the industry with regard to future employment.

COMBINED PROGRAMS IN LAW, BUSINESS AND PUBLIC ADMINISTRATION, AND CITY AND REGIONAL PLANNING

During the fourth year of the regular curriculum students in good standing in some divisions of the College of Engineering may apply for admission to special programs which will permit the completion of requirements for both the appropriate Bachelor's degree in engineering and one of the advanced or graduate degrees in law, business and public administration, or city and regional planning, in one year less than the normal period.

Ordinarily such a combined program, leading to two degrees, would constitute an eight-year course of study in the case of law and seven years in the case of business and public administration or city and regional planning. By choosing as electives courses acceptable to the other schools or colleges and by being permitted to count certain other courses as meeting requirements in both areas, students will be able to acquire the two degrees in the shortened period.

Arrangements for one or more such combined programs of study are possible for selected students in chemical, civil, electrical, and metallurgical engineering. Applications will be accepted at any time prior to the fifth year, but, for maximum flexibility and ease of program planning, the choice should be made as early as possible. Applications must be approved by both participating schools or colleges in any instance.

UNDERGRADUATE STUDIES IN AERONAUTICAL ENGINEERING

Applicants interested in the field of aeronautical engineering should apply for admission to the School of Mechanical Engineering, the School of Electrical Engineering, or the Department of Engineering Physics. In the regular five-year programs of these Schools they will obtain the fundamental scientific and humanistic courses that an aeronautical engineer must have; in addition, they may elect aeronautical engineering courses in the Graduate School of Aeronautical Engineering during their fourth and fifth years (provided that their scholastic record at that time is adequate). They can also carry out senior projects in the aeronautical field, under the direction of staff members of the School of Aeronautical Engineering. By planning their programs in this way, these students obtain an unusually sound and well-rounded aeronautical engineering education, combining the broad engineering training of Cornell's five-year undergraduate curricula with specialized

aeronautical studies of the type usually reserved for graduate students.

Applicants should mention their interest in aeronautical engineering when they apply for admission. The Director of the Graduate School of Aeronautical Engineering will assist them in planning their fourth and fifth-year programs so as to take greatest advantage of the offerings of that School.

NUCLEAR TECHNOLOGY

An elective program planned to prepare men for work in nuclear technology is available for qualified students in the Schools of Chemical, Civil, Electrical, Mechanical, and Metallurgical Engineering, and in Engineering Physics. Based on the premise that engineers will be the most productive in the nuclear power field if they are able to apply their particular field of engineering in combination with a sound knowledge of nuclear physics and related technical subjects, the program provides for a series of elective courses in the fourth and fifth years, including atomic and nuclear physics, laboratory work in nuclear measurements, principles and design of nuclear reactors, advanced heat transfer and diffusion, reactor materials, radiation damage, fuel processing, waste disposal, etc. The student interested in the nuclear power field should consult with his adviser for assistance in planning a program of courses to take advantage of the excellent opportunities available.

ENGINEERING LIBRARY

The engineering library is in Carpenter Hall, a magnificent new building finished in 1957, and given to Cornell by Walter Carpenter '10. Its inviting reading rooms and book stacks contain a basic and rapidly growing collection of books, periodicals, documents, reports, and pamphlets supporting all the branches of engineering taught in the schools and departments of the College. The resources of the library are housed in a pleasant atmosphere created by the attractive design of the building, the convenient arrangement of its facilities, and its handsome furnishings. In addition to the conventional facilities for reading and research, comfortable chairs for leisurely reading, individual study tables, and a typing and microtext reading room are provided. A staff of professional librarians furnishes reference, bibliographical, reserve, and circulation services.

A special feature of the library in Carpenter Hall is the Browsing Room. Furnished as a club, this handsome paneled room houses about 1500 selected books in the fields of the humanities and the social studies. It is designed to provide for students and faculty an inviting collection of cultural reading in an atmosphere of leisure, quiet, and dignity.

Allied and supporting literature in the basic sciences is to be found in the chemistry library, the physics library, and the mathematics

library. Historical literature in all the sciences is located in the collections of the main University Library. The library resources of Cornell total 1,800,000 volumes.

GRADUATE STUDIES

A graduate student holding a baccalaureate or equivalent degree from a college or university of recognized standing may pursue advanced work leading to a graduate degree in engineering. Such a student may enter as a candidate either for the general degrees (M.S. or Ph.D.) or for the professional degrees (M.Ch.E., M.C.E., M.E.E., M.I.E., M.M.E., M.Met.E.).

The general degrees (M.S. and Ph.D.) are available in all the fields and subdivisions of the College of Engineering. They are administered by the Graduate School and require work in both major and minor fields of study, as well as the completion of a satisfactory thesis, usually involving individual and original research. A prospective graduate student interested in obtaining an M.S. or Ph.D. should consult the *Announcement of the Graduate School* for additional information concerning these degrees and should correspond with the professor supervising the particular field of engineering representing his major interest. Students who do not completely meet the entrance requirements for these degrees may be admitted as provisional candidates or without candidacy according to previous preparation, but they must in all cases hold a baccalaureate or equivalent degree.

Professional degrees at the Master's level are available in all the Schools of the College and in the Department of Industrial Engineering. These are degrees involving specific curricula and are administered by the Engineering Division of the Graduate School. In contrast to the general degrees, they do not require work in a minor field or the presentation of a thesis based upon research studies. Students who have completed four years of appropriate work in the College of Engineering at Cornell, or any student holding a baccalaureate degree in engineering or science deemed appropriate to the proposed study, may enroll in the Engineering Division of the Graduate School and pursue work leading to these professional degrees.

Because of the great diversity that exists in the practice of the different branches of engineering, the curricula of the several professional Masters' degrees differ in content. The prospective student should consult the more detailed descriptions of the curricula of the various Schools elsewhere in this Announcement. These professional degrees should be considered to be at the five- and one-half to six-year level of university work, requiring from one to two years of additional study beyond a four-year baccalaureate degree. The required number of credit hours in each curricula may be reduced by allowing credit for

advanced work completed before entrance into the program. Professional experience substantially covering the same area as any part of the student's curriculum may, after investigation by the faculty, be given corresponding credit, provided that the credit hours earned in this way, plus the allowance for advanced work completed before entry into the program, do not exceed fifteen hours.

Information concerning graduate scholarships, fellowships, and assistantships can be obtained either from the Dean of the Graduate School or the Dean of the College of Engineering.

Prospective candidates for the degree of M.Aero.E. should apply directly to the Director of the Graduate School of Aeronautical Engineering.

COLLEGE AND UNIVERSITY REQUIREMENTS

COLLEGE REQUIREMENTS

FOR GRADUATION...Baccalaureate degrees are conferred on candidates who have fulfilled the following requirements:

1. The candidate must have been in residence and registered in the College of Engineering for the last two terms and must have satisfied the University requirements in military training and physical education and in the payment of tuition and fees.

2. He must have completed to the satisfaction of the faculty of the College of Engineering all the subjects and the elective hours prescribed in the course of study as outlined by that faculty.

3. A student who transfers to the College of Engineering, after having spent one or more terms in another college of Cornell University or elsewhere, must conform to the requirements of the class with which he graduates.

4. Each student in the first term of the freshman year in the College of Engineering must attend regularly the lectures in orientation for students in engineering.

REQUIREMENTS CHANGEABLE...The College of Engineering reserves the right to modify its curricula and specific courses of instruction, to alter the requirements for admission or for graduation, and to change the degrees to be awarded; such changes are applicable to either prospective or matriculated students at any time the College may determine.

UNIVERSITY REQUIREMENTS

MILITARY SCIENCE...As a land-grant institution chartered under the Morrill Act of 1862, Cornell offers courses in military science which include all branches of the service (Army, Navy, Air Force, and Marines). Successful completion of such courses and receipt of a bac-

calaureate degree qualify a male student for a commission in the Regular or Reserve component of the appropriate service.

Participation in military training during the first four terms is mandatory for all physically qualified undergraduate men who are United States citizens. Satisfactory completion of the basic course in military science and tactics, air science, or naval science fulfills this requirement. (See also the *Announcement of the Independent Divisions and Departments*.)

For a student entering with advanced standing, the number of terms of military training required is to be reduced by the number of terms which he has satisfactorily completed (not necessarily including military science) in a college of recognized standing. Service in the armed forces may under certain conditions also satisfy the military training requirement.

Entering students who have had previous ROTC training in secondary or military schools are requested to obtain DA Form 131 (Student's Record—ROTC) from the institution previously attended and to present it to the appropriate military department during registration. (See also page 129 of this Announcement).

PHYSICAL EDUCATION . . . All undergraduate students must pursue four terms of work, three hours a week, in physical education. Ordinarily, this requirement must be completed in the first two years of residence; postponements are to be allowed only by consent of the University Faculty Committee on Requirements for Graduation.

Exemption from this requirement may be made by the committee designated above, when it is recommended by the medical office or when unusual conditions of age, residence, or outside responsibilities require it.

For students entering with advanced standing, the number of terms of physical education required is to be reduced by the number of terms which the student has satisfactorily completed (whether or not physical education was included in his program) in a college of recognized standing.

PAYMENTS TO THE UNIVERSITY

TUITION AND OTHER FEES . . . For information concerning tuition and other fees payable to the University, see the *General Information Announcement*.

STUDENT PERSONNEL SERVICES

STUDENT PERSONNEL OFFICE

The admission of new students, the administration of scholarships in the College of Engineering, and the placement of graduates are

activities of the College which are coordinated in the Student Personnel Office. The Personnel Office, in addition to other facilities, is also available at all times to students who wish to discuss any question relating to their life in the College.

STUDENT COUNSELING

In general, the counseling of students rests with the class advisers to whom the students are assigned primarily for assistance in planning and scheduling their academic work but who will welcome students at any time to discuss other personal matters. In each school of the College, students are referred to the chairman of the scholarship committee when in financial need and to a placement adviser for assistance in vocational choice and postgraduate employment. Also, the students are free to consult with the dean, directors, department heads, and instructors not only on matters pertinent to their education and future plans, but also on personal matters. In addition, the University's Dean of Men and Dean of Women and their staffs may be consulted by students regarding their nonacademic problems. Both Deans have offices in Edmund Ezra Day Hall, Room 133.

HEALTH SERVICES AND MEDICAL CARE

These services are centered in the University Clinic or out-patient department and in the Cornell Infirmary or hospital. Students are entitled to unlimited visits at the Clinic; laboratory and X-ray examinations indicated for diagnosis and treatment; hospitalization in the Infirmary with medical care for a maximum of fourteen days each term; and emergency surgical care. The cost for these services is included in the College and University general fee. On a voluntary basis, insurance is available to supplement the services provided by the health fee. Information about such insurance may be obtained at the Student Medical Clinic. For further details, including charges for special services, see the *General Information Announcement*.

ASSISTANCE TO FOREIGN STUDENTS

The University maintains on its staff a Counselor to Foreign Students, whose duty is to look after the welfare of all students from other countries. He may be consulted on personal problems, social questions, or any other matter in which he may be helpful. His office, in Edmund Ezra Day Hall, is part of the Dean of Men and Dean of Women's Offices. It is suggested that all foreign students write him before coming to Ithaca or call on him immediately upon arrival.

FRESHMAN ORIENTATION

A series of orientation lectures is given to students in the fall term of the freshman year in the College of Engineering. Their primary purpose is to acquaint the student with the scope of each of the major fields of engineering and with the opportunities and the responsibilities of men in the engineering professions.

SCHOLARSHIPS, PRIZES, AND FINANCIAL AID

FRESHMAN SCHOLARSHIPS

General awards, open to entering students in *any* undergraduate division of the University, are described in the *Announcement of Financial Aids and Scholarships*. They include the Cornell National Scholarships, the LeFevre Scholarships, and the University Tuition Aid Scholarships. The scholarships described below are available *only* to students entering the College of Engineering.

Application blanks for all freshman scholarships may be obtained directly from the Scholarship Secretary, Office of Admissions, Edmund Ezra Day Hall.

AMERICAN SOCIETY FOR METALS SCHOLARSHIP. Established by the American Society for Metals Foundation for education and research. Normally awarded to an entering freshman in Metallurgical Engineering. Tenure one year. Award, \$400.

CHARLES R. ARMINGTON SCHOLARSHIPS IN ENGINEERING. Gift of Mr. and Mrs. R. Q. Armington, in memory of their son who was a student in Mechanical Engineering at the time of his death in 1956. Open to men students in any branch of engineering. One scholarship annually with annual stipend up to \$2000. Tenure, not limited. Selection based on balance of academic and extracurricular interests with outstanding personal characteristics.

JOHN HENRY BARR SCHOLARSHIP. Gift of Mrs. Mabel R. Barr, for a deserving student to be chosen by the University from recommendations of the Cornell Club of the Lehigh Valley. Annual award, up to \$2000. Tenure not limited. (Not available in 1958-1959.)

LAWRENCE D. BELL MEMORIAL SCHOLARSHIP. Established by the Bell Foundation, Inc. Open to men or women entering any branch of engineering. One or more awards with annual stipend up to \$1100. Tenure, not limited. Selection based on scholarship, leadership qualities, and financial need.

EDWARD P. BURRELL SCHOLARSHIPS. Gift under the will of Katherine W. Burrell, in memory of her husband. Open to men and

women entering any division of the College of Engineering. Award, up to \$700 for freshman year only. Need is an important factor in selecting the winners.

WILLIS H. CARRIER SCHOLARSHIP. Established by the Carrier Foundation, Inc. Open to entering students in the Sibley School of Mechanical Engineering. Annual award, \$750. Tenure, not limited. Selection is based on scholastic promise and financial need.

GENERAL MOTORS COLLEGE SCHOLARSHIP. Established 1957 by the General Motors Corporation. Available to men or women who are citizens of the United States entering the College of Engineering. One scholarship annually with stipend of from \$200 to \$2000 depending upon need. Tenure, unlimited. Selection based upon outstanding academic promise, general character, and financial need.

INLAND STEEL FOUNDATION SCHOLARSHIPS. Established by the Inland Steel Foundation. Annual award, \$1500. Tenure not limited. Selection is based on scholastic attainment, personal characteristics, and financial need. Summer employment may be offered to recipient by the Inland Steel Company.

MARTIN J. INSULL SCHOLARSHIP. Gift of his wife, Mrs. Virginia Insull. Open to men entering the College of Engineering. Annual award, \$1200. Tenure, not limited. Further provisions as for the McMullen Regional Scholarships (see below), except that serious financial need is an essential criterion. (Not available in 1958-1959.)

LOCKHEED NATIONAL ENGINEERING SCHOLARSHIP. Established by the Lockheed Leadership Fund. Open to entering students in the College of Engineering. Annual award, tuition and fees and \$180 for books and supplies. Tenure, unlimited. One award each year to a student who is in a field of engineering applicable to the aircraft industry and whose total personal qualities can be expected upon graduation to offer a significant contribution to the aircraft industry.

JOHN McMULLEN REGIONAL SCHOLARSHIPS. Gift under the will of John McMullen. Open to men entering any division of the College of Engineering. Annual award, up to \$1100. Tenure, not limited. Fifty or more scholarships awarded annually. Applicants will be selected on the basis of high scholastic achievement and other indications of qualities likely to produce leadership in engineering. Although financial need is not a factor in selecting the winners, full consideration will be given to need in fixing stipends.

OWENS-ILLINOIS SCHOLARSHIP. Established by Owens-Illinois. Open to men. Annual award, tuition and fees plus \$125 for books and supplies in the freshman year and \$100 annually thereafter. Tenure,

not limited. Selection will be based on scholastic achievement, personality, and financial need. Summer employment may be offered by Owens-Illinois.

PROCTER AND GAMBLE SCHOLARSHIPS. Established by the Procter and Gamble Company. Open to men or women entering the College of Engineering. Annual award, \$1215, covering tuition, fees, books, and supplies. Tenure, unlimited. Selection based on academic achievement, character, and financial need.

ALFRED P. SLOAN NATIONAL SCHOLARSHIPS. Established by the Alfred P. Sloan Foundation. Open to men entering any division of the College of Engineering. Annual award varies from a prize scholarship of \$200 to as much as \$2000, depending upon financial need. Tenure, not limited. Nine scholarships awarded annually. Applicants will be selected on the basis of high character, sound personality, leadership potential, and scientific promise.

SOLVAY SCHOLARSHIP. Established by the Solvay Process Division of Allied Chemical and Dye Corporation. Open to an entering student in chemical engineering. Award, \$1000. Tenure, one year. Selection will be based upon scholarship, personality, and financial need. (Not available in 1958-1959.)

JESSEL STUART WHYTE SCHOLARSHIP. Gift of Mrs. Anna Jessel Whyte in memory of her son. Open to an entering student in the Sibley School of Mechanical Engineering. Annual award, \$820. Tenure, not limited. Preference will be given to residents of Illinois, Iowa, Michigan, Minnesota, and Wisconsin. Further provisions as for McMullen Regional Scholarships. (Not available in 1958-1959.)

SCHOLARSHIPS AND GRANTS-IN-AID FOR UPPERCLASSMEN

Students in their sophomore year and beyond may apply for scholarship aid through the Committee on Scholarships of the School in which they are enrolled (i.e., Civil Engineering, Mechanical Engineering, etc.). Applications are available in the office of the Director of each School.

Awards are of two general types: (1) those for which the principal qualification is financial need, and (2) those for which outstanding scholastic achievement is the chief criterion. In the first category are scholarships which are essentially grants-in-aid and which have variable stipends up to full tuition in any year. Eligibility extends to any student not on scholastic probation.

The second category of awards, based on high scholastic and other attainments, consists of (1) a limited number of scholarships sponsored by industrial companies, mostly for students in their last two years of study, and (2) such vacancies as may occur in scholarships of this type usually awarded to entering students and subject to renewal.

Below are the scholarships sponsored by industrial companies and foundations. For a complete list of all scholarships and grants-in-aid available to students in the College of Engineering, see the *Announcement of Financial Aids and Scholarships*.

ALLEGHENY LUDLUM SCHOLARSHIP. Established by the Allegheny Ludlum Steel Corporation. Award, \$500. Tenure, three years. Awarded annually to a student in chemical or metallurgical engineering, normally to a student in metallurgical engineering, with primary consideration for academic record, promise of ability, and success in his field of study. Need is a secondary factor.

THE AMERICAN BRAKE SHOE SCHOLARSHIP. Established by the American Brake Shoe Company. Open to juniors and seniors or fifth year students in mechanical, chemical, or metallurgical engineering. Three scholarships of \$800 each to be awarded annually. Renewable to students in good standing.

AMERICAN SOCIETY FOR METALS SCHOLARSHIP. Established by the American Society for Metals Foundation for education and research. Award, \$400. Tenure, one year. Available to a sophomore in metallurgical engineering.

ASARCO SCHOLARSHIP. Established by the American Smelting and Refining Company. Open to a fourth or fifth year student in chemical engineering. Annual award, \$500. Selection based on scholastic achievement and leadership potential.

DOW CHEMICAL COMPANY SCHOLARSHIPS. Established by the Dow Chemical Company. Award, \$833.33. One scholarship to be awarded annually and renewable for the fourth and fifth years to a student in chemical engineering.

DRAVO CORPORATION SCHOLARSHIPS. Established by the Dravo Corporation. Open to fourth year students in civil, electrical, or mechanical engineering. One new award of \$1000 annually; may be renewed for fifth year. Selections based on scholastic ability, need, and personal characteristics.

FOUNDRY EDUCATIONAL FOUNDATION SCHOLARSHIPS. Open to all students (except freshmen) in metallurgical and mechanical engineering who are interested in preparing themselves for professional engineering work in the foundry industries. Annual award, up to \$600. Tenure, one or more years. Awarded on the basis of leadership, financial need, scholastic standing, and interest in foundry work.

HARRISON JULES LOUIS FRANK & LEON HARRISON FRANK MEMORIAL SCHOLARSHIP. Established by the above-named cor-

poration in memory of the founders of the BullDog Electric Products Company. Preference given to juniors, seniors, and graduate students in the School of Electrical Engineering who are interested in the control and distribution of electric energy. One scholarship annually in the amount of \$500, subject to renewal.

MONSANTO SCHOLARSHIP. Established by the Monsanto Chemical Company. Open to seniors in the School of Mechanical Engineering and fifth year students in the School of Chemical and Metallurgical Engineering. Award based upon academic standing, interest in chemistry, and probability of success. Financial need not considered. Annual award, \$700; tuition scholarship.

NIAGARA MACHINE AND TOOL WORKS SCHOLARSHIP IN MECHANICAL ENGINEERING. Established 1956 by the Niagara Machine and Tool Works. Award, \$1000. One scholarship annually to a student in mechanical engineering entering his fourth year who stands in the top third of his class and has been active in extracurricular affairs. Tenure, two years. Preference for students from western New York State.

THE SCOTT AWARD AT CORNELL. Established by the Scott Paper Company. One \$1000 scholarship awarded annually to an outstanding fifth year student in mechanical engineering who intends to follow an industrial career. The recipient must have demonstrated those high qualities of intellect, personality, and physical vigor associated with the Rhodes Scholars.

THE STANDARD OIL OF CALIFORNIA SCHOLARSHIPS. Established by the Standard Oil Company of California. Award, one-half tuition plus \$750 cash. Two scholarships annually to students in the fifth year of chemical engineering.

THE TRANE COMPANY SCHOLARSHIP. Established by the Trane Company of La Crosse, Wisconsin. Open to seniors in mechanical engineering with special interest in air conditioning, refrigeration, or heat transfer. Annual award, \$1000. Selection to be based on scholastic attainment, need, and leadership potential.

UNION CARBIDE ENGINEERING SCHOLARSHIPS, sponsored by Linde Air Products Company, a Division of Union Carbide and Carbon Corporation. Established 1957 by the Union Carbide and Carbon Corporation. Open to an entering student in chemical or mechanical engineering. Annual award, tuition and fees, plus \$125 for books and supplies. Tenure, five years. Academic promise and financial need will be considered in selection of winners.

WESTERN ELECTRIC SCHOLARSHIPS. Established by the Western Electric Company. Open to students in any division of the College

of Engineering. Two scholarships with annual award up to \$800 to be applied against the cost of tuition, fees, and books. Tenure, one year; may be renewed. Selection based upon need and ability in fields of study related to the Company's operations.

WESTINGHOUSE AIR ARM DIVISION SCHOLARSHIP. Established 1956 by the Westinghouse Electric Corporation. Award, \$500. One scholarship annually to a third-year student in electrical or mechanical engineering or engineering physics standing in the top third of his class. Tenure, three years.

WYMAN-GORDON SCHOLARSHIP. Established by the Wyman-Gordon Company. One award of \$1100 annually to a fifth-year student in mechanical or metallurgical engineering.

LOANS

The University maintains substantial loan funds from which students may borrow after they have been in residence for two terms and provided they are in good standing. Loans bear no interest while the student is in the University, and usually not more than 4 per cent annually after he leaves until repayment is made. Applications for loans should be made through the Office of the Dean of Men and Dean of Women.

PART-TIME CAMPUS EMPLOYMENT

Students wishing to earn a part of their living expenses by working on or near the campus during the school year should apply in advance of registration to the Office of the Dean of Men and Dean of Women in Edmund Ezra Day Hall. Freshmen are advised to meet their first year expenses by other means if possible, until by experience they have learned how much time they will have available to devote to such employment.

PRIZES

Cornell University has a considerable number of funds given for the endowment of prizes to be awarded annually. Some of these prizes are open to competition by students of the University generally. A list of them, under the title *Prize Competitions*, will be mailed on request addressed to Cornell University Announcements, Edmund Ezra Day Hall. Prizes open to competition particularly by students of the College of Engineering are:

THE FUERTES MEDALS, established by the late Professor E. A. Fuertes. The endowment provides for two gold medals. One is awarded annually by the faculty to that student of the School of Civil Engineering who is found at the end of the first term of his senior year to

have maintained the highest degree of scholarship in the subjects of this course, provided he has been in attendance at the University for at least two years. The other is awarded annually by the faculty to a graduate of the School of Civil Engineering or the recipient of a graduate degree with major in civil engineering who has written a meritorious paper upon some engineering subject tending to advance the scientific or practical interests of the profession of the civil engineer. It is desired that papers be presented on or before April 15. If a paper is presented in printed form, it will not be received if it has been printed earlier than the next preceding April 15. Neither medal is awarded unless it appears to the faculty of the School of Civil Engineering that there is a candidate of sufficient merit to entitle him to such distinction.

THE FUERTES MEMORIAL PRIZE IN PUBLIC SPEAKING, founded by the late Charles H. Baker, a graduate of the School of Civil Engineering of the class of 1886. Three prizes, one of \$100, one of \$40, and one of \$20, are offered annually to all students of the Colleges of Engineering and Architecture who are in the fifth term or beyond, for proficiency in public speaking.

THE CHARLES LEE CRANDALL PRIZES, founded in 1916 by alumni of the School of Civil Engineering. The prizes of \$75, \$50, \$35, and \$20 are awarded each year by a committee appointed by the Director of the School of Civil Engineering for the best papers written by seniors or juniors in that School on suitable subjects, provided that both the substance and the written form of the papers submitted show real merit. The prizes were established to encourage original research, to stimulate interest in matters of public concern, and to inspire in the students an appreciation of the opportunities which the profession of civil engineering offers them to serve their fellow men as intelligent and public-spirited citizens. Papers must be submitted to the Director of the School of Civil Engineering on or before March 15 of each year.

SIBLEY PRIZES. Under a gift of Hiram Sibley, made in 1884, the sum of \$100 is awarded annually in several prizes to fifth year students in mechanical engineering and electrical engineering, equally distributed, who have received the highest average in the preceding four years.

THE SILENT HOIST AND CRANE COMPANY MATERIALS HANDLING PRIZES of \$125 and \$75, established in 1950 by the Wunsch Foundation, are awarded each year for the best original papers on the subject of materials handling. This contest is open to undergraduate and graduate students of the College of Engineering.

THE J. G. WHITE PRIZE IN SPANISH. Through the generosity of James Gilbert White (Ph.D., Cornell, '85), three prizes, established in 1914, each of the value of \$100, are offered annually. One of the three,

which is awarded to an English-speaking student for proficiency in Spanish, is open to members of the junior and senior classes in the College of Engineering who are candidates for their first degree. No candidate is eligible unless he has completed successfully two terms of work in Spanish at Cornell University.

THE INSTITUTE OF AERONAUTICAL SCIENCES PRIZE. The "Student Branch Scholastic Award" of the Institute of Aeronautical Sciences is presented annually to the M.Aero.E. candidate who attains the best scholastic record for that academic year. The award consists of a certificate and a two-year free technical membership in the Institute.

GRADUATE SCHOLARSHIPS AND FELLOWSHIPS

Graduate students whose major subjects are in the various branches of engineering and who wish to be candidates for scholarship or fellowship aid should consult the *Announcement of the Graduate School* and make application to the Dean of the Graduate School. Those who are candidates for the degree M.Aero.E. should apply to the Director of the Graduate School of Aeronautical Engineering.

STUDENT HONORS AND ACTIVITIES

DEAN'S HONOR LIST

Students of the College of Engineering whose weighted average in their studies is 85 per cent or better are included annually in an Honor List compiled for the Dean. The honor students comprise approximately the highest tenth of all the students enrolled in the College.

STUDENT ACTIVITIES

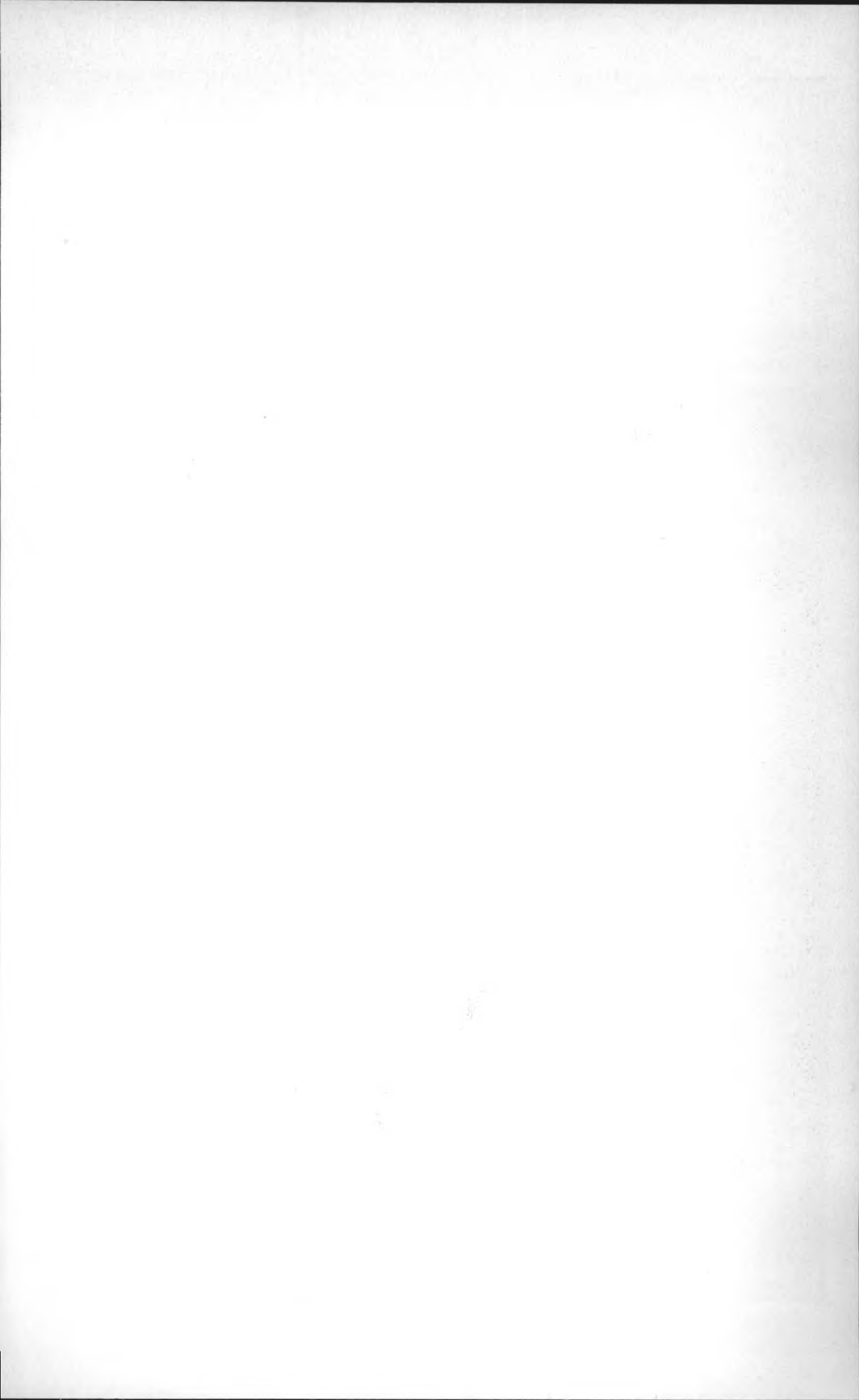
Students of the College of Engineering find many opportunities for engaging in wholesome activities outside their regular duties, and even outside the College, in company with other members of the University community. Within the College some find congenial occupation in helping to carry on the student branches of the national engineering societies, in conducting *The Cornell Engineer*, or in membership in national or local honor societies, which include Tau Beta Pi, Phi Kappa Phi, Sigma Xi, Pi Tau Sigma, Chi Epsilon, Rod and Bob, Pyramid, Atmos, Kappa Tau Chi, and Eta Kappa Nu. In the University at large there are student activities of all sorts—musical, dramatic, journalistic, social, and athletic.

ENGINEERING SOCIETIES

The College of Engineering is closely associated with the local sections of the American Society of Civil Engineers, American Society

of Mechanical Engineers, American Institute of Electrical Engineers, Society of Automotive Engineers, and Institute of Radio Engineers, many of the meetings of which are held on the campus and are participated in by the members of the College. The College also maintains active student branches of these national societies as well as of the American Institute of Chemical Engineers and the Institute of Aeronautical Sciences. The Cornell Metallurgical Society was formed in 1949 and is an affiliate of the American Institute of Mining and Metallurgical Engineers. Students in the Department of Engineering Physics formed in 1948 the Cornell Society of Engineering Physics. The meetings of such societies afford opportunities for addresses by engineers of eminence, for the presentation of papers by students, for discussion, or for contests in public speaking on engineering subjects. The School of Mechanical Engineering gives elective credit hours for activity in the student branches of the A.S.M.E.

THE CORNELL ENGINEER, a technical journal published monthly throughout the academic year, is managed and edited by undergraduates in the College of Engineering.





SCHOOL OF CIVIL ENGINEERING

THE PROFESSION of civil engineering pertains to the design, construction, and maintenance of major buildings, bridges, dams, airports, thruways, railways, canals, tunnels, pipelines, etc. Advanced civil engineering includes such work as the planning and administration of systems of transportation, flood control, city management, soil and water conservation, resource development, and sanitation.

About 20 per cent of the graduates from civil engineering serve the public as federal, state, or city employees. The other 80 per cent are widely distributed and are found in such employment as private consulting, construction management, and engineering design for engineering organizations. Future opportunities should be excellent because of expanding needs for civil engineers and the relatively small number of high school students who have elected this field as a profession since World War II.

EQUIPMENT

The principal building occupied by the School of Civil Engineering is Lincoln Hall, containing classrooms, drafting rooms, and laboratories.

The laboratories for sanitary engineering, airphoto analysis, and photogrammetric work are located in Lincoln Hall. The sanitary laboratory provides for physical, chemical, and bacteriological analyses of water and sewage and for research in general. The airphoto analysis and photogrammetric laboratories provide for interpretation and use of airphotos in all types of surveying and regional planning activities.

A fully equipped and manned machine shop is also provided in Lincoln Hall, which gives support to laboratory instruction and research.

Facilities in Thurston Hall include the testing laboratory, equipped for a wide variety of tests of cement, concrete, timber, structural steel, and other construction materials used by civil engineers.

The soil mechanics laboratory is located in a separate building and has facilities for instruction, standard laboratory work, and specialized research in soil mechanics.

The highway laboratories are housed in separate buildings and are equipped for making standard tests and for research in highway engineering. The surveying equipment is composed largely of instru-

ments purchased since 1950, including both American and foreign designs of the most modern type.

Hydraulic laboratories, situated at the outlet of Beebe Lake, are under the jurisdiction of this School. In addition to student instruction and research, these laboratories provide facilities for hydraulic investigations carried on in cooperation with government agencies and private companies.

COURSES OF STUDY

The courses of study offered by the School of Civil Engineering lead to the degree of Bachelor of Civil Engineering and are planned to provide fundamental instruction for the practice of the profession. To meet this objective, the major portion of the curriculum is definitely prescribed, both as to technical content and humanistic studies. Each student, however, is permitted to choose elective courses in various fields which can be planned to intensify his training in a specific area or to increase his general background.

COMBINED PROGRAMS....The School participates with the Law School, the Graduate School of Business and Public Administration, and the College of Architecture (City and Regional Planning) in combined programs during the fifth year; in this way the student in civil engineering may complete the requirements for the appropriate advanced or graduate degree in a period one year less than that normally required. The programs are described on page 14.

CURRICULUM (B.C.E.)

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and			
	Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	2	3
	English 111, Introductory Course	3	3	0
	Engineering 2001, Drawing	3	0	7½
	Total	15		
TERM 2	Mathematics 161, Analytic Geometry and			
	Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Chemistry 106, General Inorganic Chemistry	3	2	3
	English 112, Introductory Course	3	3	0
	Engineering 2002, Drawing	3	0	7½
	Engineering 2111, Elementary Surveying	2	0	5
	Total	17		

In addition to these courses, all freshmen must satisfy the University's requirements in military training and physical education.

		CONTACT HOURS		
		CREDIT	LEC.	LAB.
		HOURS	REC.	COMP.
TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 113, Electricity and Magnetism	2	3	2½
	Chemistry 301, Organic Chemistry	2	2	0
	Geology 113, Engineering Geology (or Economics 103)	3	2	5
	Engineering 2113, Route and Aerial Surveying ..	3	1	5
	Engineering 1151, Mechanics-Statics	3	3	0
	Total	16		
TERM 4	Physics 114, Physical Electronics and Optics	2	3	2½
	Chemistry 402, Physical Chemistry	2	2	0
	Economics 103, Modern Economic Society (or Geology 113)	3	3	0
	Engineering 2112, Advanced Surveying	3	2	2½
	Engineering 1145, Applied Mathematics	3	3	0
	Engineering 1153, Strength of Materials	3	3	2½
	Total	16		
In addition to these courses, all sophomores must satisfy the University's requirements in military training and physical education.				
TERM 5	Engineering 2114, Summer Survey Camp	5	0	0
	Engineering 1134, Strength of Materials	3	3	0
	Engineering 1152, Mechanics-Dynamics	3	3	0
	Engineering 2701, Elementary Structural Analysis	3	2	2½
	Engineering 2501, Microbiology in Engineering (or 1241)	3	2	2½
	Engineering 3630, Engineering Thermodynamics	3	3	0
	Socio-Economic Elective (or Speech 101)	3	3	0
	Total	23		
TERM 6	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 2301, Fluid Mechanics	3	3	0
	Engineering 3642, Heat Power II	2	2	0
	Engineering 2702, Elements of Metal and Timber Structures	3	0	7½
	Engineering 1241, Materials (or 2501)	3	2	2½
	Public Speaking 101 (or Socio-Economic Elective)	3	3	0
	Engineering 2602, Transportation (or 2901)	3	3	0
	Total	20		

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 7	History 165, Science in Western Civilization	3	3	0
	Engineering 4932, Electrical Engineering	3	2	2½
	Engineering 2302, Applied Hydraulics and Hydrology (or 2502)	3	2	2½
	Engineering 2704, Statically Indeterminate Structures (or 2903)	3	3	0
	Engineering 2901, Construction Methods (or 2602)	3	3	0
	Engineering 2725, Soil Mechanics (or 2715)	3	2	2½
	Total	18		
TERM 8	History 166, Science in Western Civilization	3	3	0
	Engineering 2412, Hydraulic Engineering (or 2503)	3	3	0
	Engineering 2715, Reinforced Concrete Design (or 2725)	3	0	6
	Engineering 2903, Economics of Engineering (or 2704)	3	3	0
	Engineering 2502, Water Supply & Sewerage Systems (or 2302)	3	2	2½
	Engineering 2610, Highway Engineering (or 1212)	3	2	2½
	Total	18		
TERM 9	Engineering 2902, Engineering Law (or 2904)	3	3	0
	Engineering 2503, Water and Waste Treatment (or 2412)	3	2	2½
	Engineering 3231, Accounting (or ILR 293)	3	2	2½
	Engineering 1212, Materials Laboratory (or 2610)	3	1	5
	Engineering 2720, Foundations	3	2	2½
	Elective (Free)	3		
	Total	18		
TERM 10	Engineering 2904, Public Administration (or 2902)	3	3	0
	Industrial and Labor Relations 293, Survey of Industrial and Labor Relations (or 3231)	3	3	0
	Engineering 2713, Structural Design	3	0	6
	Electives (Free)	9		
	Total	18		

Grand total for ten terms: 179 credit hours including summer survey camp, but not including military training or physical education.

COMBINED PROGRAMS

CIVIL ENGINEERING AND BUSINESS AND PUBLIC
ADMINISTRATION (B.C.E. and M.B.A. or M.P.A.)

During the fifth year the student will be registered in both schools. A specialized program will be worked out with the Graduate School of Business and Public Administration within the framework of the Civil Engineering curriculum as amended by the following approved substitutions:

BPA 110, Administrative Accounting, for Eng. 3231

BPA 140, Finance, for socio-economic elective

BPA 120, 121, Economics and Business History, for History 165, 166

BPA 100, 101, Administration, for Eng. 2904 and ILR 293

Under special circumstances, and by petition to the faculty, other substitutes may be approved.

During the sixth year, and after receiving the B.C.E. degree, the student will be registered only in the Graduate School of Business and Public Administration.

CIVIL ENGINEERING AND CITY AND REGIONAL
PLANNING (B.C.E. and M.R.P.)

After approval by both the School of Civil Engineering and the College of Architecture, the fifth year student may follow a special program within the framework of the Civil Engineering curriculum as amended by the following approved substitutions:

BPA 218, Municipal Administration, for Eng. 2904

Arch. 700, 401, History of Architecture and City Planning, for History 165, 166

Arch. 710, 711, Principles and Practice of City Planning, for ILR 293 and socio-economic elective

Arch. 718 or 720, Field Problems in Urban Planning, for three elective courses

Under special circumstances, and by petition to the Faculty, other substitutes may be approved.

During the sixth year, and after receiving the B.C.E. degree, the student will be registered in the College of Architecture as a candidate for the M.R.P. degree.

CIVIL ENGINEERING AND LAW (B.C.E. and LL.B.)

During the fifth year, the student will be registered in both schools. He will follow a specialized program including at least twenty semester hours in the Law School and within the framework of the Civil Engineering curriculum as amended by the following approved substitutions:

Twenty credit hours of Law School courses may be substituted for the fifteen elective hours and any two of the required courses, Engineering 2713, 2902, 2904, or History 166.

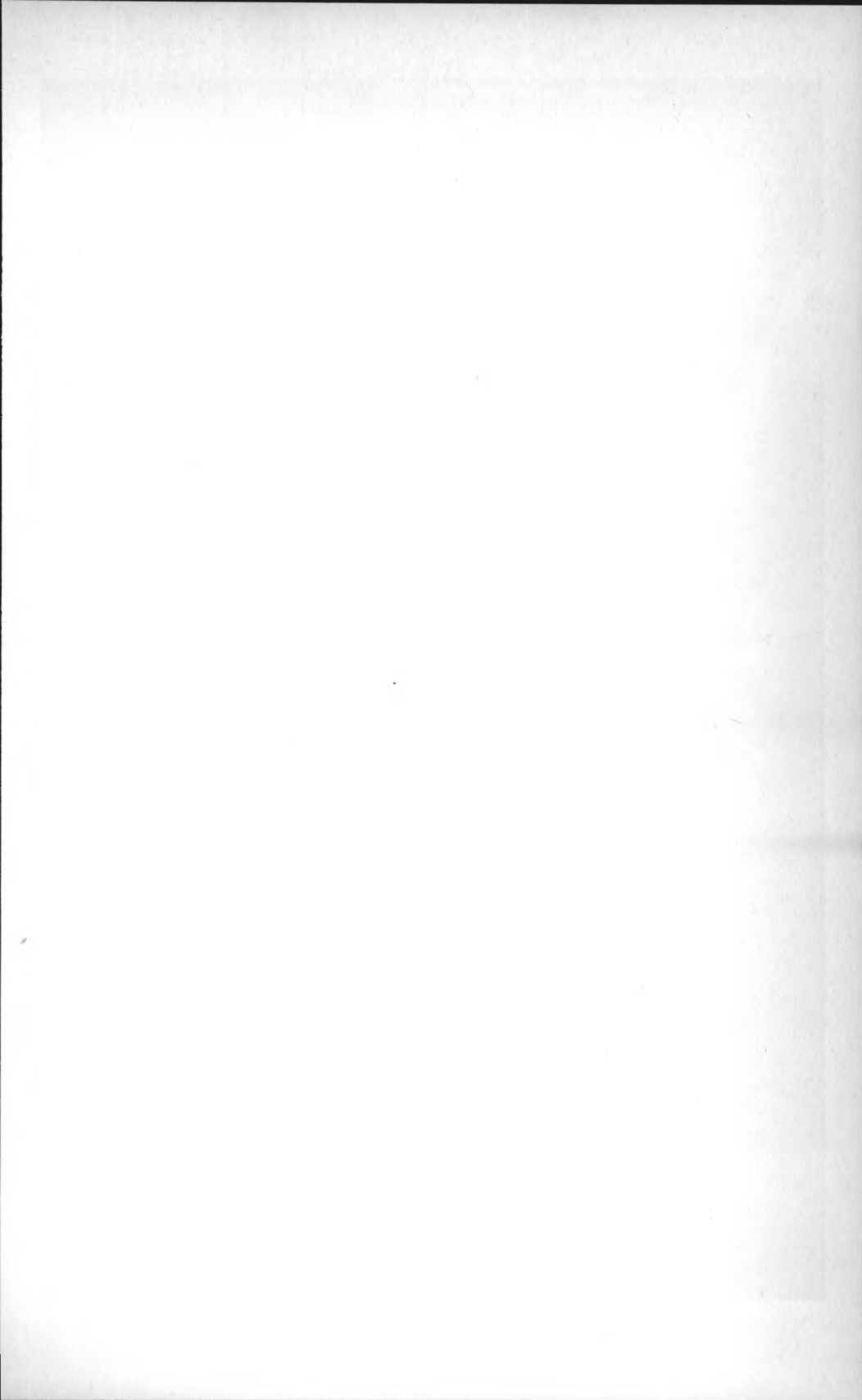
Under special circumstances, and by petition to the faculty, other substitutions may be approved.

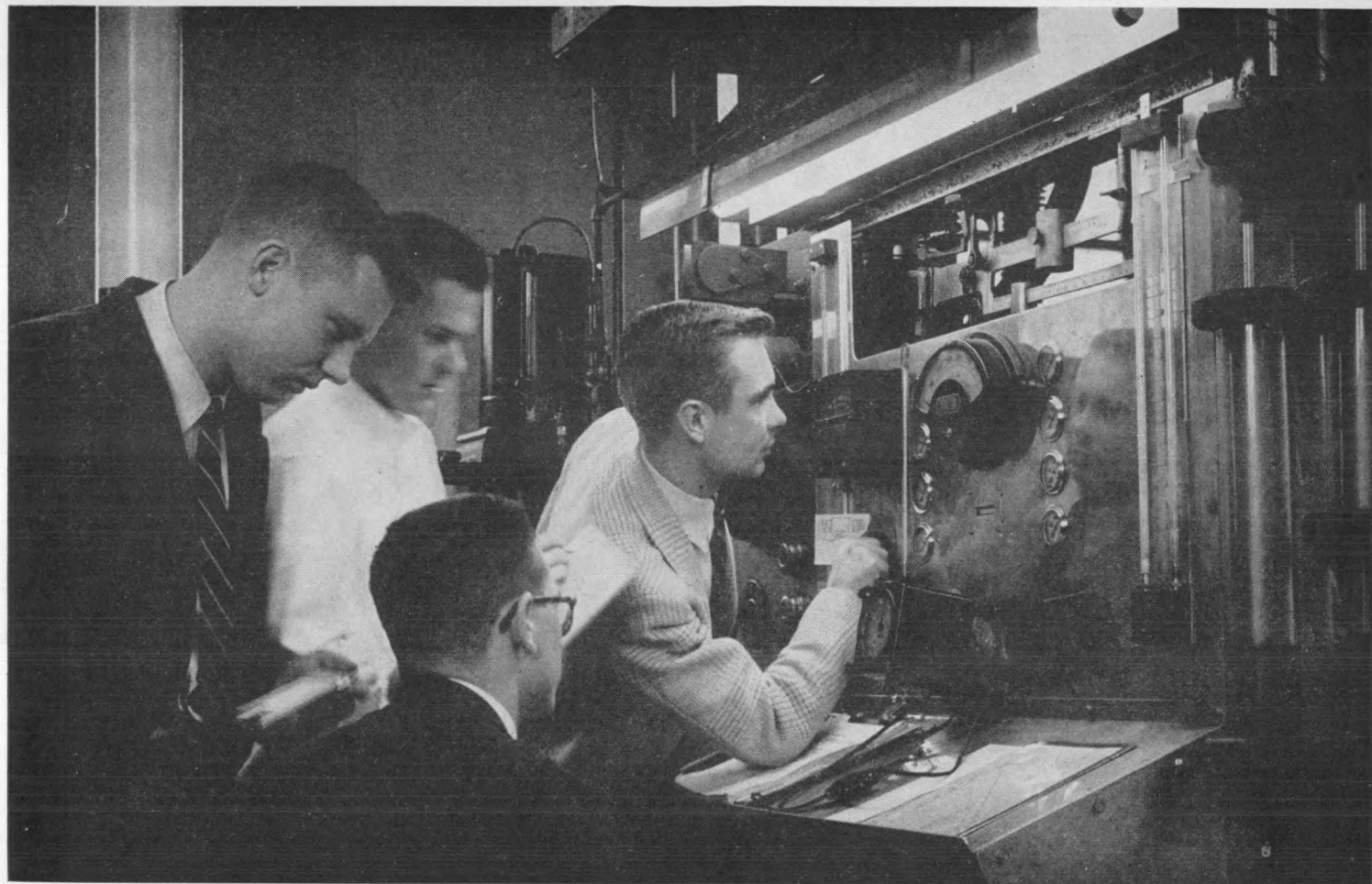
During the sixth year, and after receiving the B.C.E. degree, the student will be registered only in the Law School.

SPECIAL GRADUATE PROGRAM

Qualified students may, by special permission, follow a program which will permit them to obtain the M.C.E. degree in less than one extra year. To meet the requirements for the M.C.E. degree, a minimum of 45 semester hours of approved advanced courses must be satisfactorily completed, of which up to 30 may be taken prior to the receipt of the B.C.E. degree.

Students will be accepted into the program at the end of the fourth year, but, for maximum flexibility and ease of scheduling, the decision to follow this program should be made as early as possible.





SIBLEY SCHOOL OF MECHANICAL ENGINEERING

EQUIPMENT

THE SIBLEY School of Mechanical Engineering, named in recognition of Hiram Sibley, an early business associate of Ezra Cornell, is housed primarily in Upson Hall. This magnificent building is the gift of Maxwell M. Upson and was completed in 1957 as part of the new engineering quadrangle at the south end of the campus. Adjacent to Upson Hall is Kimball Hall, which contains all the equipment used by the School for instruction in materials processing. Excellent engineering library facilities are provided in Carpenter Hall, completed in 1957. This building forms the western end of the engineering quadrangle.

Upson Hall has been designed to provide the finest laboratory and classroom facilities. These laboratories include: the machine design laboratory, for instruction and research in photoelasticity, balancing, vibration, stress, lubrication, and wear of machines and machine members; the steam laboratory, for instruction and research involving steam power, including a small scale power plant consisting of the boiler, turbogenerators, control panels, and auxiliary equipment; the internal combustion engine laboratory with spark ignition and diesel engines, as well as CFR engines for fuel research; a turbomachinery laboratory for gas turbines; air conditioning and refrigeration laboratory for work in this field; a solar energy laboratory; methods engineering laboratory, for motion and time study and work measurement; the constant temperature room; the heat transfer and flow measurement laboratories; a group of laboratories for specialized research and student project research. All of these laboratories are supported by a well equipped machine shop, staffed with qualified personnel for maintenance and the making of specialized research equipment. In Kimball Hall, in addition to a basic machine shop, there are a production machine tools laboratory and a measurement laboratory, including a constant temperature room for precise measurements.

Other laboratories in the College of Engineering that play an important role in the training of mechanical engineers include the materials testing laboratory, heat treatment laboratory, and the metallography laboratory for the determination of the physical properties of engineer-

ing materials under various conditions. These laboratories are contained in Thurston Hall, which adjoins Kimball Hall.

OUTLINE OF THE INSTRUCTION

The object of the instruction in this School is to lay as broad and substantial a foundation of general and technical knowledge and provide as much training in engineering practice in the fields of mechanical engineering and engineering administration as can well be imparted in a school.

Students of mechanical engineering are instructed primarily in the utilization of nature's sources of energy and materials for the benefit of mankind, through the development and application of prime movers, machinery, and processes of manufacture; thus, they have to do mainly with things dynamic. The province of the mechanical engineer includes the design, construction, operation, and testing of steam engines, steam turbines, steam generating apparatus, and power plant auxiliaries, internal combustion engines, hydraulic machines, pumping engines, railway equipment, compressed-air machines, ice making and refrigerating machinery, equipment for heating and ventilating and air conditioning, machine tools, mill equipment, and transmission machinery. The work of the mechanical engineer further includes the planning of power plants and factories, the selection and installation of their equipment, the development of systems of operation and manufacturing processes, and the organization and administration of plants and industries. In addition, the mechanical engineer may engage in scientific research in the innumerable branches of this field.

The general plan of the curriculum is to give a thorough training in mathematics and the basic sciences of physics and chemistry leading to the fundamental engineering sciences and technological courses. Parallel with this training are a group of courses in the social sciences and liberal fields to develop a better understanding of the social, political, and economic world in which the engineer must assume responsibility for leadership. The outline of the course of study shows how the training is integrated as well as the depth and scope of the subject matter to give the young engineer a sound foundation for his future professional growth.

Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

PROJECT AND ELECTIVES

During the last three years, provision is made for the choice of elective courses and a senior project in the student's major field of study.

His project may be an individual one or a group project in a technical, managerial, or related field for the purpose of applying to one or more basic problems the fundamental concepts he has been taught in the preceding years and for the purpose of developing the ability to do work of an original nature.

The project may be in any one of many branches, such as management, industrial engineering, thermal engineering, internal combustion engines, heat engineering, heating, ventilating and air conditioning, refrigeration engineering, automotive engineering, aeronautical engineering, mechanical design, experimental stress analysis, design development, advanced mechanics and strength of materials, engineering materials, experimental engineering, materials processing, tool engineering, welding design, structural engineering, physics, nuclear engineering, electrical engineering, and other fields related to mechanical engineering.

The 35 hours of electives in the curriculum provide an opportunity for the student to select a wide variety of courses offered in the University, depending upon his interests and objectives. To ensure a reasonable breadth of training in fields other than engineering, beyond those courses already specified, the student must elect twelve credit hours of work from the fields of English, government, history, languages, philosophy, psychology, economics, sociology and anthropology, speech and drama, literature, music, fine arts, or the classics. To acquire some depth of training, it is strongly urged that a student take at least six credit hours of work in a given field.

A minimum of eleven credit hours of electives must be in approved courses in the College of Engineering. Usually these courses will be related to the student's project, but he does have the opportunity to pursue engineering specialties of great interest to him.

INDUSTRIAL AND ENGINEERING ADMINISTRATION

The training of engineers for the field of production engineering or industrial engineering has been an integral part of the Sibley School of Mechanical Engineering for the past fifty years. The increasing scientific developments underlying the operation of works and plants in many industries have put additional emphasis on the need for a sound background in such areas as materials, design, statistical procedures, materials processing, gaging and inspection, methods engineering, cost accounting and production engineering including product analysis, plant layout, engineering economy, and production control, all of which are required in the curriculum.

The emphasis is on the engineering aspects, with due regard for the importance of the human and personnel factors involved in successfully organizing and managing an industrial enterprise.

Modern managerial decisions involve the integration of many complex variables. Problems of utilization of machines, men, and materials must be given careful consideration to obtain a decision economically sound from an over-all point of view. To cope with these problems and to give the student a solid foundation for eventual control and direction of these efforts, special programs of study have evolved at Cornell.

The student interested in this field can select suitable electives to further his training in such areas as psychology, industrial marketing and research, advanced statistics for quality control and analysis, personnel management, industrial organization, advanced methods engineering, production control, and operations research, or additional work in economics or in standard costs and control.

The existence of a School of Industrial and Labor Relations, a College of Arts and Sciences, and other divisions of the University on the same campus as the College of Engineering makes possible combinations of elective courses that are available at few other technical schools in the country.

A student interested in industrial engineering will find a unique and comprehensive group of courses, all within the framework of a strong curriculum leading to the B.M.E. degree, available to him. A special booklet describing the program in more detail is available on request.

INDUSTRIAL COOPERATIVE PROGRAM

The School participates in the Engineering Industrial Cooperative Program providing periods of industrial experience interspersed among regular terms of study. The Program is described on page 13.

PROFESSIONAL MASTERS' DEGREES: M.M.E. AND M.I.E.

In addition to the graduate programs available to engineers in the Graduate School, leading to the M.S. and Ph.D. degrees, the College of Engineering has recently instituted a graduate program leading to professional Masters' degrees. Among the degrees offered are the Master of Mechanical Engineering (M.M.E.) and the Master of Industrial Engineering (M.I.E.).

Programs leading to both professional degrees are course programs providing advanced training in specified areas. To receive either degree, a student must complete 45 credit hours of work at an advanced level. This is the equivalent of three semesters of work over and above that usually required in a regular four-year program leading to a Bachelor's degree in engineering. By the proper choice of electives, candidates for the five-year B.M.E. degree at Cornell may complete the requirements for either the M.M.E. or M.I.E. in one additional semester. Thus, both the B.M.E. and a Master's degree could be earned in five and one-half years.

Specialized programs for an M.M.E. degree in the area of machine design are available in the fields of analysis and development, automatic machinery, and power machinery; in the area of thermal engineering in the fields of combustion engines, heat transfer and fluid dynamics, nuclear and thermal power, and refrigeration and air conditioning.

Specialized programs for the M.I.E. degree are available in the areas of manufacturing engineering, methods engineering, cost control, industrial statistics, and operations research.

For further information concerning the programs for professional Masters' degrees, see the *Announcement of the Graduate School*, and the brochures entitled *Graduate Programs in Industrial Engineering* and *Graduate Programs in Mechanical Engineering*.

EMPLOYMENT AFTER GRADUATION

Graduates in mechanical engineering find employment in the design, construction, testing, and operation of prime movers and other machinery, and of complete plants in their own related fields, and in sales engineering and industrial research and development. They serve also as planners of new projects and processes, and as aeronautical engineers, air-conditioning engineers, industrial engineers, power-plant engineers, refrigeration engineers, research engineers, and teachers of engineering—to mention only a few of the many special fields open to them. With the instruction in liberal subjects and those related to administration and management coupled with the technical training, they have special qualifications to develop into leaders in their chosen fields.

SCHOLASTIC REQUIREMENTS

A student in the School of Mechanical Engineering who fails in any term to earn a passing grade in 15 hours, with a grade of 70 or better in 11 hours, may be placed on probation. If he fails in any term to pass 12 hours he may be dropped from the School.

CURRICULUM (B.M.E.)

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and			
	Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	2	3
	English 111, Introductory Course	3	3	0
	Engineering 3111, Drawing and Descriptive			
	Geometry	3	1	5
	Engineering 3001, Introductory Engineering	1	2	0
	Total	16		

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Chemistry 106, General Inorganic Chemistry ...	3	2	3
	English 112, Introductory Course	3	3	0
	Engineering 3112, Mechanical Drafting	3	1	5
	Engineering 3002, Introductory Engineering	2	2	0
Total		17		

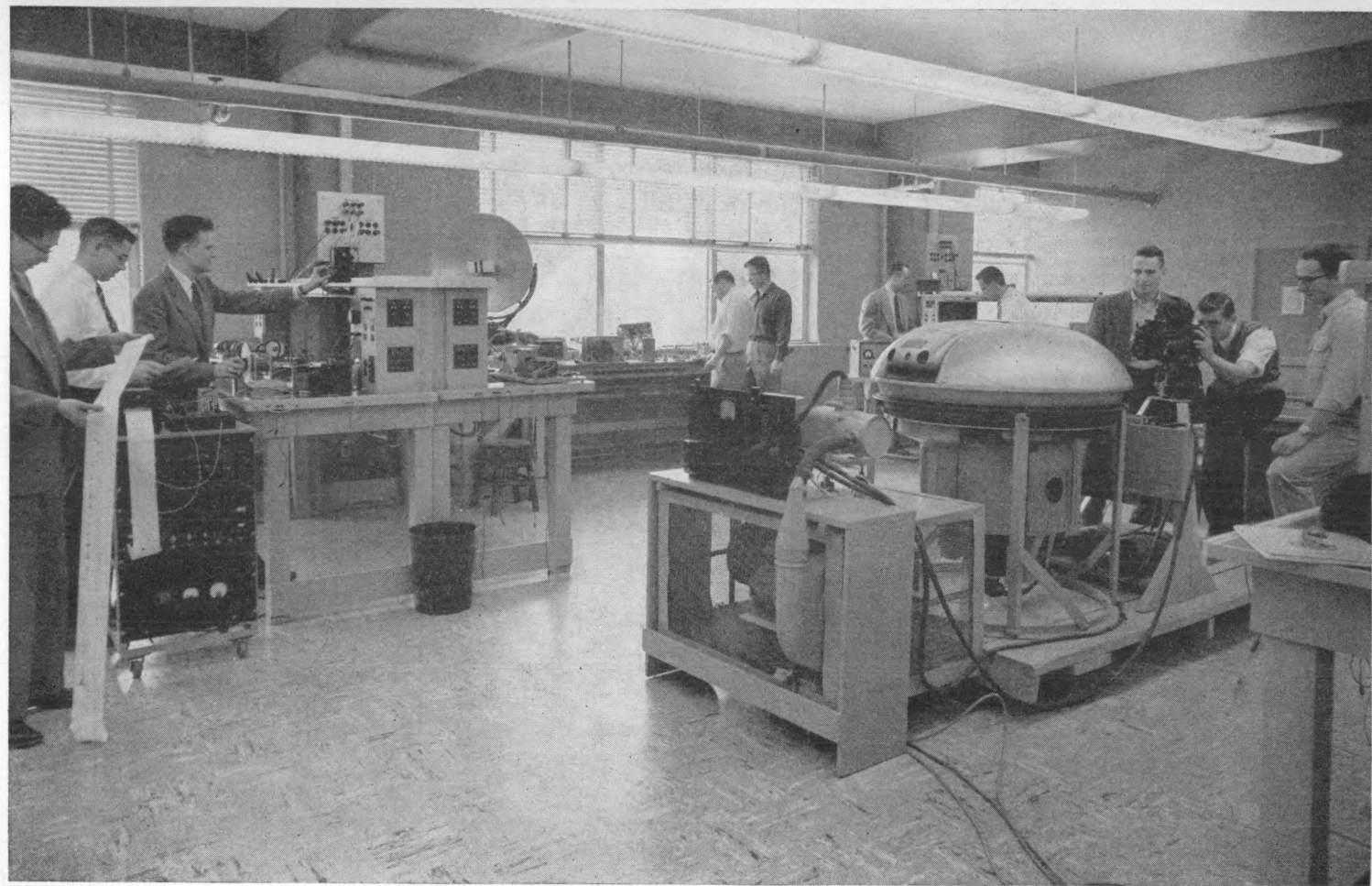
In addition to taking these courses, all freshmen must satisfy the University's requirements in physical education and in military training.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Chemistry 301, Organic Chemistry	2	2	0
	Engineering 1151, Mechanics—Statics	3	3	0
	Engineering 3241, Statistics	3	2	2½
	Engineering 6110, Casting, Working, and Welding of Metals (or Engineering 3406)	2	1	2
Total		16		
TERM 4	Physics 118, Electronics and Optics	3	3	2½
	Chemistry 402, Physical Chemistry	2	2	0
	Engineering 1153, Strength of Materials	3	2	2½
	Engineering 1155, Applied Mathematics	3	3	0
	Engineering 3262, Methods Engineering	3	1	5
	Engineering 3406, Materials Processing (or Engineering 6110)	2	1	2½
Total		16		

In addition to taking these courses, all sophomores must satisfy the University's requirements in physical education and in military training.

TERM 5	Engineering 1241, Engineering Materials	3	2	2½
	Engineering 3351, Mechanism	3	2	2½
	Engineering 3601, Thermodynamics	3	3	0
	Engineering 1152, Mechanics—Dynamics	3	3	0
	Engineering 3246, Industrial Accounting	2	1	2½
	Engineering 3404, Production Machine Tools (or Engineering 3405)	2	1	2½
	Electives	3	Arr.	Arr.
Total		19		

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 6	Engineering 1242, Engineering Materials	3	3	0
	Engineering 3352, Dynamics of Machinery	3	3	0
	Engineering 3602, Thermodynamics	3	2	2½
	Engineering 3603, Fluid Properties and Mass Flow	3	3	0
	Engineering 3247, Principles of Cost Control	3	2	2½
	Engineering 3405, Gage Laboratory (or Engineering 3404)	1	0	2½
	Electives	3	Arr.	Arr.
	Total	19		
TERM 7	Engineering 3604, Flow Processes and Energy Transfer	3	2	2½
	Engineering 3605, Heat Transfer	3	2	2½
	Engineering 3353, Design of Machine Members..	3	2	2½
	Engineering 1243, Engineering Materials Laboratory	3	2	2½
	Engineering 3263, Production Engineering	3	1	5
	Electives	3	Arr.	Arr.
	Total	18		
TERM 8	Engineering 3354, Design of Machines	3	1	5
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 3264, Production Engineering	3	1	5
	Engineering 3606, Thermal Engineering Laboratory	3	1	2½
	Engineering 6112, Metallurgy of Casting, Working, and Welding	2	2	0
	Electives (including Engineering 3607 or 3608 or 3609)	6	Arr.	Arr.
	Total	20		
TERM 9	Project	3	Arr.	Arr.
	Engineering 4932, Electrical Engineering	3	2	2½
	Engineering 1154, Strength of Materials	3	3	0
	Electives	11	Arr.	Arr.
	Total	20		
TERM 10	Project	3	Arr.	Arr.
	Engineering 4933, Electrical Engineering	3	2	2½
	Public Speaking 101	3	3	0
	Engineering 3041, Nonresident Lectures	1	1	0
	Electives	9	Arr.	Arr.
Total		19		
Total for ten terms		180		



SCHOOL OF ELECTRICAL ENGINEERING

FACILITIES

EARLY in 1955 the School of Electrical Engineering moved into Phillips Hall, a new building especially designed to house the School. Phillips Hall provides ideal instructional, administrative, and research facilities. The library, established through a generous gift from the McGraw-Hill Book Company in memory of the first director of the School, and known as the Alexander Gray Memorial Library, is housed in Carpenter Hall as a part of the combined Mechanical, Electrical, and Civil Engineering Library.

Laboratory facilities include the electrical machinery laboratories, with a great variety of both direct- and alternating-current machinery; the electrical measurements and standardization laboratory, equipped for instruction in the checking of meters and secondary standards and in the precise measurements of electrical and magnetic quantities; the radio and communication laboratory, including microwave and ultra-high-frequency laboratories; the industrial electronics laboratory, for the study of electronic power and control devices; the electronics apparatus and project laboratory, for the construction of electronic apparatus by students according to their own designs; the vacuum tube laboratory, for the construction and testing of electron tubes; the servomechanism laboratory, for the study of closed loop control systems; the illumination laboratory, and the television and pulse technique laboratory; the analog computer laboratory, and the digital computer laboratory.

In addition to these general laboratories, facilities available for instruction and research include the radio-astronomy laboratory, engaged primarily in basic research; the antenna laboratory, for the investigation of directional characteristics of antennas; the ionospheric laboratory; the high voltage research laboratory; the a-c network calculator, designed to study problems arising in complex electrical networks; and the fluid network analyzer, designed to solve problems of pressure and flow in fluid distribution systems by means of electrical analogies.

The laboratories for instruction and research are supported by a well-equipped model shop and a technicians' shop. These facilities provide a means for constructing experimental equipment for the senior projects as well as developing equipment for laboratories of instruction and providing special experimental equipment for research activities.

This servomechanism laboratory, in conjunction with a digital and analog computer laboratory, provides for experimental studies fundamental to automation.

PROGRAM OF STUDIES

The curriculum leading to the degree of Bachelor of Electrical Engineering is intended to create in the student an understanding of the meaning and the application of those laws of nature that are basic in the practice of electrical engineering and to develop a general knowledge of the origins and the trends of modern society. Through the first eight terms, all students follow the same program of technical studies; in the last two terms interest in one or more of the subdivisions of electrical engineering may be developed. Courses in administration and the humanities are distributed throughout the curriculum in accordance with the student's increasing comprehension. In all, there are thirty-six hours of courses in the administrative field and the humanities in the curriculum. Of these, nine hours are specified, and twenty-seven are elective. In addition to these thirty-six hours, there are nine free elective hours that the student may take in the humanities if he so desires.

Students who show proficiency in the first term of the introductory course in English may substitute any nontechnical course for the second term of Introductory English.

The curriculum reflects the convictions of the faculty that the modern engineer is fully equipped only if his traditional ability to manage devices and processes is accompanied by a knowledge of men and an awareness of their needs.

INDUSTRIAL COOPERATIVE PROGRAM

The School participates in the Engineering Industrial Cooperative Program, providing periods of industrial experience interspersed among regular terms of study. The Program is described on page 13.

THE FRESHMAN YEAR

Since the curriculum of the freshman year in electrical engineering is essentially the same as the curricula in mechanical engineering and engineering physics, transfer of a student between any two of these curricula may occur before the third term without loss of time. The freshman curricula in civil engineering and in chemical and metallurgical engineering differ to such an extent from the curriculum in electrical engineering that a transfer into one of these curricula is almost certain to require a lengthening of the student's program.

CLASS ADVISERS

An experienced member of the faculty acts as adviser to each new freshman class that enters the School of Electrical Engineering. With the sophomore year the class is assigned to another adviser who gen-

erally continues to serve until the class graduates, counseling each student in regard to curriculum, registration, scholarship, and other matters of the academic program. In addition, he tries to be helpful in the solution of personal problems that the student may bring to him.

Because responsibility for approval of the registration of each student is vested in the class adviser, no cancellation of courses or other changes in program may be initiated without his knowledge and approval. If the student desires a program of courses which the class adviser does not approve, the student may seek approval of the program by petition to the faculty of the School of Electrical Engineering.

SCHOLASTIC REQUIREMENTS

To remain in good standing, a student must either (1) pass the courses for which he is registered two weeks after the beginning of the term and have a weighted average of not less than 70%, or (2) if one course is failed or is canceled, the weighted average of the remaining courses must not be less than 75%. A student not meeting this requirement may be warned, placed on probation, or dropped from the School.

ELECTIVE COURSES

The curriculum in electrical engineering allows each student to choose a considerable number of elective courses during the later years of the curriculum. Some of the elective credit hours can be chosen without restriction, some must be nontechnical in the sense that they lie completely outside the field of engineering technology, and some must be either advanced courses in the sciences on which electrical engineering is based or in electrical engineering. The opportunity thus afforded for contact with the broader phases of education offered by the University as a whole tends to expand the student's mental horizon and to develop him as a well-rounded citizen.

The program of the fifth year includes two three-hour courses, designated as "Project." These are elective courses in the important respect that the student makes his own selection of the topic or problem which he will investigate under the general supervision of a faculty member. It is expected that each student will choose a problem closely related to his major interest in electrical engineering.

There are forty-five elective credit hours in the curriculum in electrical engineering. Twenty-seven of these must be nontechnical, nine must be technical, and nine are completely free. In order to realize the objective of the curriculum to broaden the education of the student and at the same time provide some depth in the cultural subjects of his choice, the 27 nontechnical elective hours must be selected as follows:

Three hours must be chosen from each of three of the following five categories and three additional hours must be chosen from two of the three categories in which the first three hours have been selected. The remaining twelve nontechnical elective hours may be chosen from any group.

GROUP 1. History, economics, accounting, government

GROUP 2. Psychology, sociology, anthropology

GROUP 3. The biological and physical sciences, excluding chemistry and physics

GROUP 4. Literature and foreign languages

GROUP 5. Philosophy, music, fine arts, speech, and drama

Nine elective credit hours must be selected from courses in electrical engineering, mathematics, or physics. At least one of the courses so selected must contain laboratory work. A course so selected must not contain a great amount of material that is essentially equivalent to that in required courses in the curriculum.

Acceptable courses are designated as follows:

1. Courses in electrical engineering numbered less than 4900.
2. Courses in mathematics numbered greater than 300.
3. Courses in physics numbered greater than 209, except 236.

The courses, elected in fulfillment of the nine-hour technical elective requirement, serve as a core for advanced studies in a particular phase of electrical engineering. Students may specialize in power systems and machinery, in industrial electronics and control, in radio and communications, in illumination, or in applied mathematics and physics. Alternatively, some students find it advisable to take advanced courses that lie in more than one of these specialties.

In addition to the twenty-seven nontechnical elective hours enumerated above and the nine technical elective hours, there are nine free elective hours. These may be chosen from among any courses in the University* for which prerequisites are satisfied, including those in the foregoing list. By carefully planning the use of electives, students may carry out extensive programs of study in other divisions of the University during the fifth year of the curriculum.

In many cases students choose to combine all or some portion of the free-elective requirements with the technical-elective requirements in order to emphasize certain studies in electrical engineering. Some of the many fields of studies along with their related courses are listed below. These groupings of courses are not intended to imply that a student must confine his studies to any one field but are presented for general information.

COMMUNICATION CIRCUIT ANALYSIS AND NETWORKS

- 4511—Radio Communication Theory I
- 4563—Pulse Technique in Communication and Radar
- 4564—Transmission of Information
- 4571—Advanced Communication Networks

ELECTRIC POWER SYSTEMS

- 4351—Power Systems I
- 4352—Power Systems II
- 4353—Power Systems III
- 4371—High-Voltage Phenomena

ELECTRON TUBES AND TRANSISTORS

- 4526—Electron Dynamics
- 4527—Microwave Electronics
- 4565—Electromagnetic Theory
- 4529—Transistors

FEEDBACK CONTROL SYSTEMS

- 4711—Servomechanisms I
- 4712—Servomechanisms II
- 4810—Introduction to Electronic Computers
- 1175—Nonlinear Mechanics

ILLUMINATION

- 4611—Introductory Illumination
- 4612—Illumination Engineering
- 4615—Illumination Seminar
- Phys. 215—Physical Optics
- Psych. 207—Perception

INDUSTRIAL ELECTRONICS

- 4411—Electronic Control Equipment
- 4415—Advanced Electronic Controls
- 4421—Electronic Power Converters

MATHEMATICS

- 611—Higher Calculus I
- 612—Higher Calculus II
- 613—Methods of Applied Mathematics I
- 614—Methods of Applied Mathematics II
- 621—Mathematical Methods in Physics I
- 622—Mathematical Methods in Physics II

COLLEGE OF ENGINEERING

MICROWAVE RADIO ANTENNAS

- 4565—Electromagnetic Theory
- 4512—Radio Communication Theory II
- 4568—Antennas

NUCLEAR TECHNOLOGY

- 8311—Nuclear and Reactor Physics
- 8351—Nuclear Measurements Laboratory
- 5505—Advanced Heat-Transfer and Diffusion
- 5760—Special Topics in Nuclear Engineering

PHYSICS

- 210—Advanced Laboratory
- 225—Electricity and Magnetism I
- 236—Electricity and Magnetism II
- 243—Atomic and Molecular Physics
- 254—Electronic Properties of Solids and Liquids

POWER MACHINERY

- 4321—Advanced Electrical Machine Theory
- 4326—Advanced Power Laboratory

COMMUNICATION SYSTEMS

- 4511—Radio Communication Theory
- 4531—Television Systems
- 4563—Pulse Technique in Communication and Radar
- 4551—Radio Aids to Navigation

RADIO AND COMMUNICATION

- 4511—Radio Communication Theory
- 4565—Electromagnetic Theory
- 4512—Radio Communication Theory II
- 4516—Radio and Communication Laboratory
- 4517—Radio and Communication Laboratory

RADIO WAVE PROPAGATION

- 4565—Electromagnetic Theory
- 4568—Antennas
- 4566—Radio Waves I
- 4567—Radio Waves II

Credit hours in advanced military science and tactics or air or naval science may be counted, to the extent of nine, toward the requirements of the baccalaureate degree. Six hours so credited are considered to lie

within the free-elective area of the curriculum and three in the "non-technical" group.

COMBINED PROGRAMS IN LAW AND BUSINESS AND PUBLIC ADMINISTRATION....Students in the School of Electrical Engineering may apply for admission to special programs which will permit the completion of requirements for the B.E.E. degree in five years and the LL.B. in seven years or the M.B.A. or M.P.A. in six years. Such a program requires approval of the two schools involved and double registration in the fifth year. This results in reducing the time required for the second degree by a year.

WAR SERVICE EXPERIENCE AND COURSES....Provision is made for veterans to obtain some credit toward the baccalaureate degree for war service experience or courses. The student should consult his class adviser.

CURRICULUM (B.E.E.)

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Chemistry	3	2	3
	Engineering 3117, Descriptive Geometry	2	0	5
	Engineering 3402, Machine Tool Processes	2	1	2½
	(or Engineering 6110, Casting, Working, and Welding of Metals)	(2)	(1)	(2)
	English 111, Introductory Course	3	3	0
	Physical Education	0	-	3
	Total	16		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Heat, Sound, and Geometrical Optics	3	3	2½
	Chemistry 106, General Chemistry	3	2	3
	Engineering 3118, Mechanical Drafting	2	0	5
	Engineering 6110, Casting, Working, and Welding of Metals	2	1	2
	(or Engineering 3402, Machine Tool Processes)	(2)	(1)	(2½)
	English 112, Introductory Course	3	3	0
	Physical Education	0	-	3
	Total	16		

In addition to these courses, all freshmen must satisfy the University's requirements in military training and physical education.

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 3	Mathematics 163, Analytic Geometry and			
	Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Engineering 1151, Mechanics	3	3	0
	Engineering 2131, Surveying	1	0	2½
	Nontechnical Elective	3	—	—
	Engineering 4110, Basic Electrical Engineering ..	3	2	3
	Physical Education	0	—	3
	Total	16		
TERM 4	Mathematics 607, Applied Mathematics for			
	Electrical Engineers	3	3	0
	Physics 118, Physical Optics and Atomic Physics..	3	3	2½
	Engineering 1153, Mechanics	3	3	0
	Engineering 3630, Engineering Thermodynamics	3	3	0
	Engineering 4111, Basic Electrical Engineering ..	3	2	3
	Physical Education	0	—	3
	Total	15		
In addition to these courses, all sophomores must satisfy the University's requirements in military training and physical education.				
TERM 5	Chemistry 401, Physical Chemistry	3	3	0
	A course in Economics	3	3	0
	Engineering 1153, Mechanics of Materials	3	3	0
	Engineering 4112, Alternating Current Circuits ..	3	2	3
	Engineering 4116, Electric Circuit Laboratory....	3	1	3
	Nontechnical Elective	3	—	—
	Total	18		
TERM 6	Engineering 1241, Engineering Materials	3	3	0
	Engineering 4113, Transmission Lines and Filters	3	2	3
	Engineering 4121, Electron Tubes and Circuits ...	4	2	6
	Engineering 4216, Electrical Machinery			
	Laboratory	4	2	3
	Nontechnical Elective	3	—	—
	Total	17		
TERM 7	Engineering 2331, Fluid Mechanics	3	3	0
	Engineering 4122, Electronic Circuit Elements ...	4	3	3
	Engineering 4221, Alternating Current Machinery	4	2	3
	Engineering 4114, Transients in Linear Systems..	3	2	3
	Nontechnical Elective	3	—	—
	Total	17		

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 8	Physics 214, Atomic, Nuclear, and Electron			
	Physics	3	3	0
	Engineering 3341, Machine Design	4	3	2½
	Engineering 4123, Electronic Circuit Elements ...	4	3	3
	Engineering 4226, Electrical Machinery			
	Laboratory	4	2	3
	Nontechnical Elective	3	—	—
	Total	18		
TERM 9	Engineering Reports 4021	3	3	0
	Free Electives	6	—	—
	Nontechnical Electives (see page 49)	3	—	—
	Senior Project 4091	3	—	—
	Technical Electives (see page 49)	3	—	—
	Nonresident Lectures 4041	0	1	0
	Total	18		
TERM 10	Free Electives	3	—	—
	Nonresident Lectures 4042	1	1	0
	Nontechnical Electives (see page 49)	6	—	—
	Senior Project 4092	3	—	—
	Technical Electives (see page 49)	6	—	—
	Total	19		
	Total for 10 Terms	170		

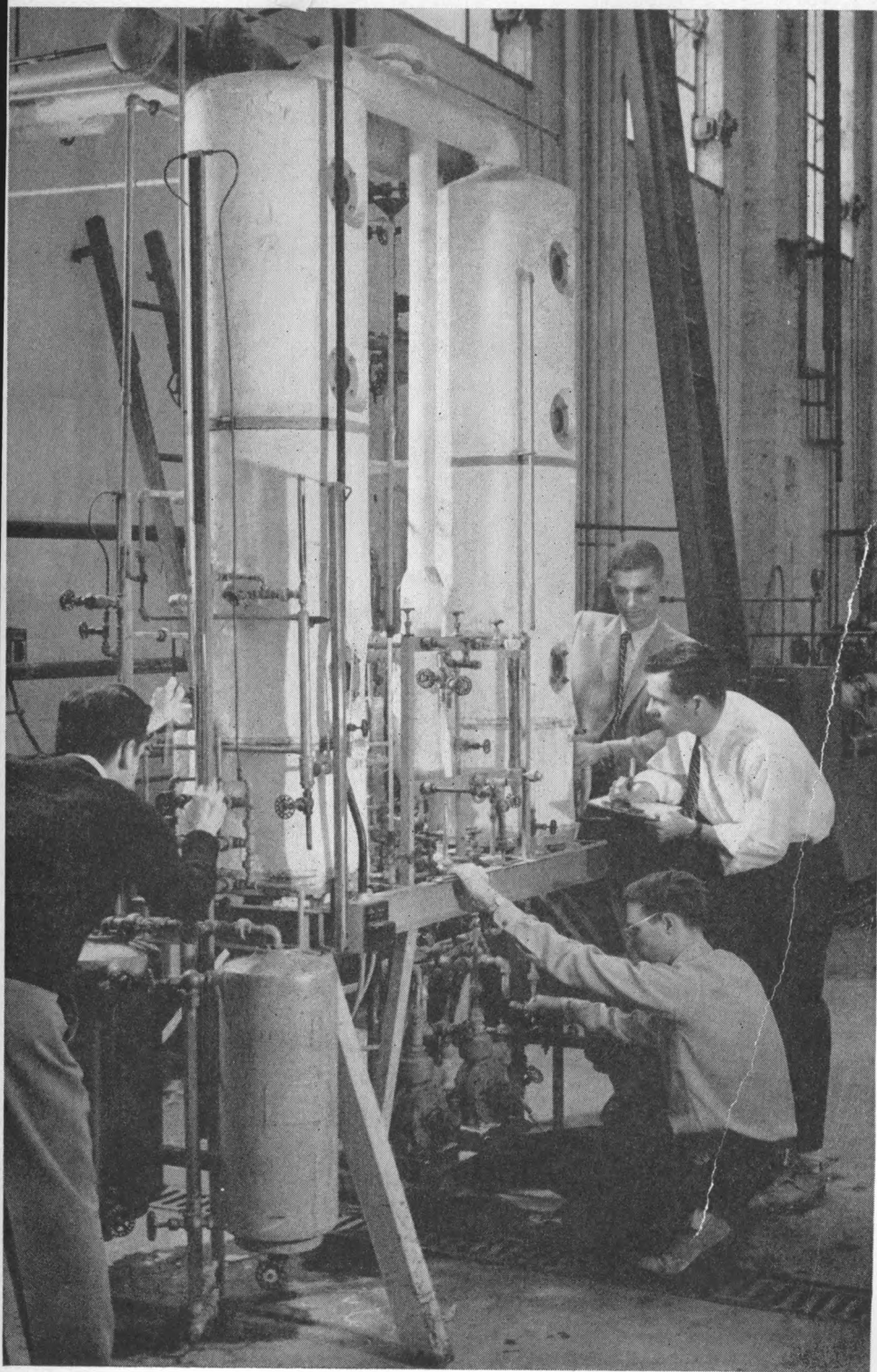
MASTER OF ELECTRICAL ENGINEERING

The School of Electrical Engineering offers a curriculum type of professional degree at the Master's level. The general requirements for this degree are stated on page 16. Of the 45 credit hours stated in the general requirements, the M.E.E. degree requires 6 hours of project 4091 and 4092, 12 hours in electrical engineering taken from the courses listed below, 6 hours taken in physics courses numbered greater than 209 except 236, 6 hours of advanced mathematics courses numbered greater than 306, and 15 hours from any of the aforementioned groups.

4011	4351	4501	4529	4565	4615
4090	4352	4511	4531	4566	4711
4115	4353	4512	4541	4567	4712
4123	4371	4516	4551	4568	4713
4226	4411	4517	4561	4571	4810
4321	4415	4526	4563	4611	4815
4326	4421	4527	4564	4612	4820

It is possible for a student to earn the M.E.E. in one semester after receiving the five-year B.E.E. degree by properly choosing his elective courses so as to meet the above requirements. If this is done, all but ten of the above required hours can be completed within the normal ten terms, leaving these ten for the eleventh term. In the eleventh term, five completely free elective hours must also be taken to meet the requirement of the Graduate School that fifteen credit hours be taken for a full semester's work beyond the baccalaureate. All course work to be counted toward the M.E.E. degree requirements must be passed with a minimum grade of 80.

Although an exceptional student may complete the B.E.E. requirements in four and one-half years and the M.E.E. in one additional term, such a program is not encouraged and is permitted only when the student has maintained a cumulative average of 85 and is considered otherwise capable of successfully completing the program.





SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING

FACILITIES

THE SPECIALIZED training in chemical and metallurgical engineering is given in Olin Hall of Chemical Engineering and in the laboratories for foundry practice and metal working. The courses in chemistry are given in Baker Laboratory of Chemistry.

Olin Hall of Chemical Engineering was provided through the generosity of Franklin W. Olin as a memorial to his son Franklin W. Olin, Jr. This modern and well equipped building, with about 105,000 square feet of available floor space, provides lecture-room, recitation-room, and laboratory facilities for instruction and research in chemical and metallurgical engineering.

The unit operations laboratory, which is about one hundred feet long and fifty feet wide, extends through three floors and houses semi-plant-scale equipment for both instruction and research in chemical engineering. It is served by a traveling crane and by its own shops and analytical laboratory. Twenty-five small laboratories provide research facilities for both undergraduate and graduate students. Olin Hall also contains special research laboratories such as the Geer Laboratory for Rubber and Plastics, biochemical engineering laboratories, and rooms and equipment for studying instrumentation and automation, microscopy, the use of radioactive material, etc.

The unit processes laboratory of metallurgical engineering offers facilities for instruction and research in ore dressing, furnace design, atmosphere control, smelting and refining, electrodeposition and heat treatment. Equipment is also available for forming metals mechanically by means of drawing, rolling or forging, or by powder metallurgy processes.

The laboratories for physical metallurgy and metallography are equipped with metallurgical microscopes and metallographs, with supplementary equipment for sample preparation and testing. X-ray diffraction equipment is available for supplementing the microscopical techniques.

The welding and brazing laboratories include facilities for manual and automatic arc welding, gas welding and brazing, inert-gas-shielded

arc welding, atomic-hydrogen arc welding, resistance spot welding, and gas cutting.

In the foundry laboratories, melting facilities include an electric arc furnace, cupola furnace, and numerous gas-fired and crucible furnaces. Molding may be done manually or by machine utilizing a variety of molding techniques including shell-molding and plaster-of-paris molding. Diecasting and permanent mold casting facilities are also available.

CHEMICAL ENGINEERING

PROGRAM OF STUDIES

Cornell University inaugurated a five-year curriculum in chemical engineering in 1932. Long experience with the five-year course has proved its value in offering excellent opportunities to the undergraduate student to obtain thorough training in his chosen field. The five-year program in chemical engineering permits a greater amount of study in nontechnical fields, plus the opportunity to take more specialized work in the later years. Project courses in research and design are given in the fifth year after a student has completed most of his basic work. Such projects require the application of much of the subject matter covered in the basic courses and point out the engineer's need for a firm foundation in the sciences.

The School of Chemical and Metallurgical Engineering has the excellent cooperation of strong departments of chemistry, mathematics, and physics, the sciences that make up most of the course work of the first two years. Chemical engineering has always been closely allied with chemistry, and undergraduate students in chemical engineering complete the basic chemistry required of a chemistry major in the College of Arts and Sciences. Advanced chemistry courses may be elected in the last two years.

Instruction in the basic principles of chemical engineering starts in the second year and extends through the fifth year. Each succeeding year both extends and broadens the scope of the chemical engineering courses so that a student has the proper training to handle advanced work in his field. The project courses in the fifth year are designed to encourage individual work and initiative under conditions that are equivalent to those found in the process industries.

Courses in English, speech, and history are required, giving the student an introduction to nontechnical courses. In the last two years, twenty-one credits of electives are made available. They are reserved for the later years so that better selection of electives may be made because of the greater maturity and experience possessed by students at this level. Selected specialization at an advanced level is also possible

since basic work has been completed. No restrictions are placed on the choice of electives, but each student must submit a coordinated plan indicating the electives he proposes to take and outlining the objectives to be achieved. Some nontechnical courses must be included and many students choose all their electives outside of the field of engineering.

OPTIONS

Specialized work is offered in biochemical engineering, petroleum, plastics and rubbers, business administration, nuclear engineering, instrumentation and automation, industrial and engineering administration, and reaction kinetics. The two-year sequence of electives at an advanced level allows students to arrange programs that are the equivalent of options in these fields. The exact sequence of courses to be selected for advanced training is not specified since it depends on the student's interests and capabilities. Exceptional students are allowed to register for graduate courses in these fields.

Those students in chemical engineering who are interested particularly in the financial and administrative aspects of engineering may register jointly in the School of Chemical and Metallurgical Engineering and in the Graduate School of Business and Public Administration during their fourth and fifth years and may then, by continuing in the Graduate School of Business and Public Administration for one additional year after receiving the first degree in engineering, be awarded the degree of Master of Business Administration or Master of Public Administration. In this way it is possible for a student to receive both the degree in engineering and the degree in business or public administration after a total period of residence of six years.

Students in chemical engineering who contemplate entering the legal profession may register jointly in the School of Chemical and Metallurgical Engineering and in the Law School of Cornell University in the fifth year of the course in chemical engineering and may count this year of work toward the degree of Bachelor of Laws as well as toward the degree in engineering.

EMPLOYMENT AFTER GRADUATION

Graduates in chemical engineering find employment in the design, development, operation, and administration of chemical engineering plants. There is also a demand for men with chemical engineering training for technical sales work in the chemical industries and for editorial work on technical publications. Some graduates in chemical engineering continue their specialized training as graduate students in chemistry or chemical engineering to prepare for positions as research

chemists or research engineers. Among the major fields of employment for graduate engineers today are the manufacture of synthetic organic chemicals; plastics, synthetic fibers, and rubber; petroleum refining; soap and detergents; etc. Many groups of industries that, in former years, had need for only a few men with chemical engineering training are today requiring such men in increasing number. Among these relatively new fields of major employment are the food industries, the atomic-power industry, and the recovery and purification of the several so-called "rare" or "unusual" metals that are becoming increasingly important.

SCHOLASTIC REQUIREMENTS

A student in the School of Chemical and Metallurgical Engineering who does not receive a passing grade in every course for which he is registered, or who fails in any term or summer session to maintain an average grade of 75 per cent, may be dropped or placed on probation.

If in the opinion of the faculty of the School concerned, a student's general record is unsatisfactory, the student may be refused permission to continue his course even though he has met the minimum requirements in respect to the number of hours of work passed and the grades in those hours. Students who fall behind in their work may be warned, put on probation, or dropped, either from an individual course or from the University, at any time during the term.

Students who so desire may change from the curriculum in chemical engineering to that in metallurgical engineering, or from the curriculum in metallurgical engineering to that in chemical engineering, at any time before the beginning of the fifth semester without loss of time or credit.

CURRICULUM (B.Ch.E.)

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 1	Chemistry 113, Introductory Inorganic Chemistry	4	3	3
	Physics 115, Mechanics	3	3	2½
	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	English 111, Introductory Course	3	3	0
	Engineering 3117, Drawing and Descriptive Geometry	2	0	4
	Engineering 5000, Orientation	0	1	0
		<hr/>		
	Total	15		

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 2	Chemistry 114, Introductory Inorganic Chemistry	4	2	6
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	English 112, Introductory Course	3	3	0
	Engineering 3118, Drawing and Descriptive Geometry	2	0	4
	Engineering 5000, Orientation	0	1	0
	Total	15		

In addition to taking the above courses, all freshmen must satisfy the University's requirements in physical education and military training.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Chemistry 307, Introductory Organic Chemistry..	3	3	0
	Chemistry 311, Organic Chemistry Laboratory ...	2	0	6
	Chemistry 224, Introductory Quantitative Analysis	4	2	6
	Engineering 5101, Introductory Chemical Engineering	2	2	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Total	17		

TERM 4	Engineering 1156, Applied Mathematics	3	3	0
	Chemistry 308, Introductory Organic Chemistry..	3	3	0
	Chemistry 312, Organic Chemistry Laboratory...	2	0	6
	Engineering 5102, Introductory Chemical Engineering	2	2	0
	Engineering 1151, Mechanics	3	3	0
	Physics 118, Physical Electronics and Optics	3	3	2½
	Public Speaking 101	3	3	0
	Total	19		

In addition to taking the above courses, all sophomores must satisfy the University's requirements in physical education and military training.

TERM 5	Chemistry 403, Introductory Physical Chemistry..	3	3	0
	Chemistry 411, Physical Chemistry Laboratory ..	2	0	5
	Engineering 1152, Mechanics	3	3	0
	Engineering 5203, Chem. Eng. Technology	2	2	0
	Engineering 6255, Materials of Construction	3	3	0
	Engineering 5851, Chemical Microscopy	3 or 0	1	5
	Engineering 3253, Cost Accounting	0 or 3	2	2½
	Engineering 5303, Unit Operations of Chemical Engineering	3	3	0
	Total	19		

COLLEGE OF ENGINEERING

		CONTACT HOURS		
		CREDIT	LEC.	LAB.
		HOURS	REC.	COMP.
TERM 6	Chemistry 404, Introductory Physical Chemistry..	3	3	0
	Chemistry 412, Physical Chemistry Laboratory...	2	0	5
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 5204, Chem. Eng. Technology	2	2	0
	Engineering 6256, Materials of Construction	3	3	0
	Engineering 3253, Cost Accounting	3 or 0	2	2½
	Engineering 5851, Chemical Microscopy	0 or 3	1	5
	Engineering 5304, Unit Operations of Chemical Engineering	3	3	0
	Total	19		
TERM 7	Engineering 5353, Unit Operations Laboratory..	3	2	3
	History 165, Science in Western Civilization.....	3	3	0
	Engineering 5103, Chemical Engineering Thermodynamics	3	3	0
	Engineering 5711, Library Use	1	1	0
	Engineering 5745, Statistical Methods in Process Industries	3	3	0
	Electives	6	-	-
	Total	19		
TERM 8	Engineering 5354, Unit Operations Laboratory..	3	2	3
	History 166, Science in Western Civilization.....	3	3	0
	Engineering 5104, Chemical Engineering Thermodynamics	3	3	0
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 5701, Plant Inspections	1	-	-
	Electives	6	-	-
	Total	19		
TERM 9	Engineering 4932, Electrical Engineering	3	2	2½
	Engineering 5603, Chemical Equipment	2	2	0
	Engineering 5605, Chemical Plant Design	2	1	3
	Engineering 5503, Chemical Engineering Computations	2	2	0
	Engineering 5953, Senior Project	2	0	6
	Engineering 5746, Chemical Engineering Economics	3	3	0
	Electives	3	-	-
	Total	17		

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 10	Engineering 4933, Electrical Engineering	3	2	2½
	Engineering 5504, Chemical Engineering Computations	2	2	0
	Engineering 5604, Chemical Equipment	2	2	0
	Engineering 5606, Design Project	2	1	3
	Engineering 5954, Research Project	2	0	6
	Electives	6	—	—
	Total	17		

Elective courses may be taken in any college of the University. The selection must be approved by the student's adviser.

REQUIREMENTS FOR THE DEGREE OF M.Ch.E.

A candidate must complete a minimum of 54 credit hours distributed as follows (see page 16 for additional information):

1. A minimum of 18 credit hours in the basic physical sciences of physics, chemistry, and mathematics. Normally, 6 credit hours of mathematics, and 3 to 9 credits in both physics and chemistry, must be selected from the following courses to make up the total of 18 credits. (See the *Announcement of the College of Arts and Sciences* for descriptions of courses numbered below 1000.)

Chemistry (3 to 9 credits): 320, 365, 366, 375, 380, 385, 395, 396, 431, 440, 448, 455, 461, 472, 480, 482, 491, 575, 576, 585, 586, Biochemistry 101, 102, 201, 202.

Physics (3 to 9 credits): 214, 215, 225, 236, 243, 244, 254, 350, 380, 675, 775, 8121, 8122, 8311, 8351.

Mathematics (6 credits): 501–502, 611–612, 613–614, 615, 616.

2. At least 18 credits in chemical engineering selected from the following courses: 1255–6, 5104, 5106, 5312, 5503–4, 5505, 5506, 5603–4, 5605–6–7–8+, 5741, 5742, 5743, 5745, 5746, 5748, 5749, 5760, 5851, 5953–4–5–6+.

Normally, a student will be expected to complete 5503–4 and a project course (marked +). No candidate will receive credit for courses taken before the fourth year, even though such courses are included in this list.

3. To complete degree requirements, all courses in excess of the minimum 36 hours specified above are considered to be electives even if they are taken in the basic sciences or chemical engineering. All elective courses must be approved by the student's adviser and the Graduate Committee of the School.

SPECIALIZED TRAINING....Within the basic requirements for the degree of M.Ch.E., programs may be arranged which give the student



advanced training in various specialized fields employing chemical engineers. They may be planned to meet the requirements and special interests of the individual student. Specific programs are available in biochemical engineering, chemical engineering administration, nuclear engineering, and polymeric materials, but others may be arranged.

METALLURGICAL ENGINEERING

Metallurgical engineers are concerned with the science and technology of metals, including:

- a. Extracting metals from their ores.
- b. Alloying metals with other metals to confer desired properties.
- c. Casting or mechanically forming metals into useful shapes.
- d. Joining metals to other metals by welding or brazing.
- e. Heat treating metals to develop optimum properties for specific applications.
- f. Selection of metals and alloys for specific applications.

The field of metallurgical engineering requires basic knowledge and understanding, not only of the engineering aspects of different metallurgical operations, but of the science of metals as well. As a result of the varied aspects of metallurgical engineering, there is a tendency for specialization into two rather broad divisions: extractive metallurgy, concerned with the production of metals from mineral ores, and physical metallurgy, concerned with the shaping, joining, alloying and heat treatments of metals.

Extractive metallurgy might be called chemical metallurgy since reduction of ores to metals involves the reactions and processes of chemistry and chemical engineering. On the other hand, the specialist in physical metallurgy relies heavily on basic physical and mechanical principles, and requires a thorough understanding of physics, particularly of the solid state.

PROGRAM OF STUDIES

The curriculum leading to the degree of Bachelor of Metallurgical Engineering provides a broad coverage of the theoretical and applied aspects of both extractive and physical metallurgy, built upon intensive training in the basic sciences—mathematics, physics, and chemistry—and in the allied fields of engineering.

Basic subjects consume the major part of the first two years, with metallurgical courses beginning in the second year to give an introduction to physical and extractive metallurgy. The metallurgical content of the curriculum progressively increases in amount and complexity in the last three years, with emphasis on basic principles and correlation of information. The sequence of courses in the principal branches of

Metallurgical microscope reveals the inner structure of a metal (inset) upon which its properties depend.

extractive and physical metallurgy is closely coordinated. Graduates are qualified for work in either extractive or physical metallurgy.

A number of unrestricted electives permits the student to supplement the required courses with more advanced sequential study in the basic sciences or in metallurgical and other engineering fields, or to pursue other subjects of special interest outside engineering. These electives also afford enough flexibility in the curriculum so that students may in many cases transfer from other divisions of the Engineering College as late as the end of their second year without over-all loss of time.

OPTIONS

Students in metallurgical engineering may utilize their elective credits to take specialized and sequential work in such fields as business administration, industrial and engineering administration, law, or nuclear technology. The specific sequence of courses depends on the student's interests, as well as upon the nature of the specialized study.

The option in nuclear technology, for example, includes courses in nuclear and reactor physics, nuclear measurements and heat transfer, and prepares students for work in the design, development, and operation of nuclear reactors.

Students interested particularly in administrative aspects of engineering may co-register in the School of Chemical and Metallurgical Engineering and in the Graduate School of Business and Public Administration during their fourth and fifth years and may then, by continuing in the latter school for one additional year after receiving the degree of B.Met.E., be awarded the degree of Master of Business Administration or Master of Public Administration. These combined programs involve a total period of residence of six years.

Students who contemplate entering the legal profession may register jointly in the School of Chemical and Metallurgical Engineering and in the Law School in their fifth year in metallurgical engineering, and may count this year of work toward both the engineering degree and the degree of Bachelor of Laws.

EMPLOYMENT AFTER GRADUATION

Since metals play an important role in almost every kind of engineering endeavor, graduates of the curriculum in metallurgical engineering are not restricted to a narrow field of activity, but instead have a diversity of opportunities for employment. Metallurgical engineers are in demand not only for basic metallurgical industries, such as those producing steel or copper, but also in industries that fabricate or consume metals. Thus, they may work in the chemical or petroleum

industries, advising as to the most suitable alloy for a specific service and ensuring satisfactory performance; or, metallurgical engineers may work in the automobile, aircraft, or electronic industries, all important consumers of metals, and thus dependent upon their proper selection and utilization. Graduates may enter the utilities industries which furnish transportation, communication, and power generation. Opportunities are excellent for metallurgical engineers in nuclear engineering, especially for students that pursue the nuclear engineering option.

A number of qualified graduates pursue advanced studies leading to the degrees of Master of Science or Doctor of Philosophy, as the opportunities for fundamental research or development are especially good.

SCHOLASTIC REQUIREMENTS

The scholastic requirements in metallurgical engineering are identical with those in chemical engineering (see page 62).

METALLURGICAL ENGINEERING CURRICULUM (B.Met.E.)

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 1	Chemistry 113, Introductory Inorganic Chemistry	4	3	3
	General Physics 115, Mechanics	3	3	2½
	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	English 111, Introductory Course	3	3	0
	Engineering 3117, Drawing and Descriptive Geometry	2	0	4
	Engineering 3403, Fundamentals of Machine Tools	1	1	1½
	Engineering 6000, Orientation	0	1	0
	Total	16		
TERM 2	Chemistry 114, Introductory Inorganic Chemistry	4	2	6
	General Physics 116, Wave Motion, Sound and Heat	3	3	2½
	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	English 112, Introductory Course	3	3	0
	Engineering 3118, Drawing and Descriptive Geometry	2	0	4
	Engineering 6000, Orientation	0	1	0
	Total	15		

In addition to taking the above courses, all freshmen must satisfy the University's requirements in physical education and military training.

COLLEGE OF ENGINEERING

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 3	Chemistry 224, Introductory Quantitative Analysis	4	2	6
	Chemistry 301, Engineering Chemistry (Organic)	2	2	0
	General Physics 117, Electricity and Magnetism..	3	3	2½
	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Geology 712, Metallurgical Raw Materials	3	3	0
	Engineering 6111, Introductory Metallurgy	2	1	2
	Total	17		
TERM 4	General Physics 118, Physical Electronics and Optics	3	3	2½
	Engineering 1156, Applied Mathematics	3	3	0
	Engineering 1151, Mechanics	3	3	0
	Engineering 3253, Cost Accounting	3	2	2½
	Engineering 6501, Metallurgical Calculations	2	1	2½
	Public Speaking 101	3	3	0
	Total	17		
In addition to taking the above courses, all sophomores must satisfy the University's requirements in physical education and military training.				
TERM 5	Chemistry 403, Introductory Physical Chemistry..	3	3	0
	Chemistry 411, Physical Chemistry Laboratory ..	2	0	5
	Engineering 1152, Mechanics	3	3	0
	Engineering 6255, Materials of Construction	3	3	0
	Engineering 5851, Chemical Microscopy	3	1	5
	Engineering 6203, Smelting and Refining	3	3	0
	Total	17		
TERM 6	Chemistry 404, Introductory Physical Chemistry..	3	3	0
	Chemistry 412, Physical Chemistry Laboratory ..	2	0	5
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 6204, Smelting and Refining	3	3	0
	Engineering 6256, Materials of Construction	3	3	0
	Engineering 6811, Introductory Metallography...	3	1	5
	Total	17		
TERM 7	Engineering 6103, Metallurgical Engineering Thermodynamics	3	3	0
	Engineering 5711, Library Use and Patents	1	1	0
	Engineering 6253, Unit Processes in Metallurgy ..	3	1	2½
	Engineering 6311, Physical Metallurgy	2	2	0
	Engineering 6351, Physical Metallurgy Laboratory	3	1	5
	Electives	6	-	-
	Total	18		

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 8	Engineering 6114, Metallurgy of Casting, Working, and Welding	3	2	2½
	Engineering 6254, Unit Processes in Metallurgy..	3	1	2½
	Engineering 6312, Physical Metallurgy	2	2	0
	Engineering 6701, Plant Inspections	1	0	0
	Engineering 4931, Electrical Engineering	3	2	2½
	Electives	3	0	0
	Engineering 6221, Advanced Process Metallurgy..	3	0	0
	Total	18		
TERM 9	Engineering 5745, Statistical Methods in Process Industries	3	3	0
	Engineering 6953, Senior Project	2	0	6
	Engineering 4932, Electrical Engineering	3	2	2½
	History 165, Science in Western Civilization	3	3	0
	Electives	8	—	—
	Total	19		
TERM 10	Engineering 6602, Metallurgical Design	3	3	0
	Engineering 6954, Senior Project	2	0	6
	Engineering 4933, Electrical Engineering	3	2	2½
	History 166, Science in Western Civilization	3	0	0
	Electives	6	—	—
	Total	17		

Elective courses may be taken in any college of the University. The selection must be approved by the student's adviser.

REQUIREMENTS FOR THE DEGREE OF M.Met.E.

A candidate must complete a minimum of 54 credit hours distributed as follows:

1. A minimum of 18 credit hours in the basic physical sciences of physics, chemistry, and mathematics. Normally, 6 credit hours of mathematics, and 3 to 9 credits in both physics and chemistry, should be selected. The courses that may be taken will ordinarily fall within the following list: see the *Announcement of the College of Arts and Sciences* for descriptions of those numbered below 1000.

Chemistry: 431, 455, 461, 472, 480, 485, 491, 492, 575, 576, 585, 586.

Physics: 214, 215, 225, 236, 243-244, 254, 258, 588, 675, 775, 8121-8122, 8311, 8512, 8517.

Mathematics: 201, 501-502, 611-612, 613-614, 615-616, 621-622, 641-642, 721, 1156*

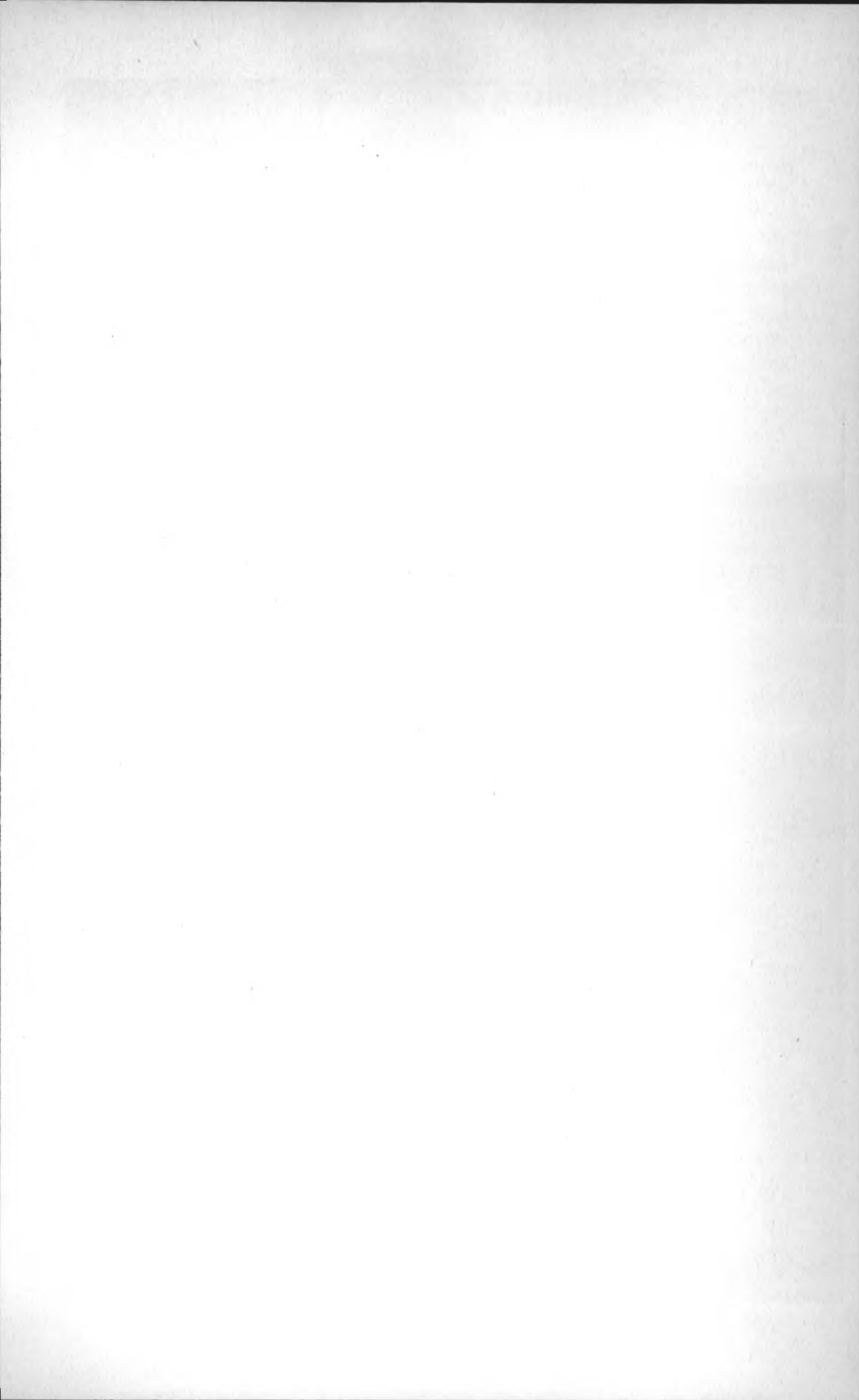
*Cornell students will not receive advanced degree credit for this course.

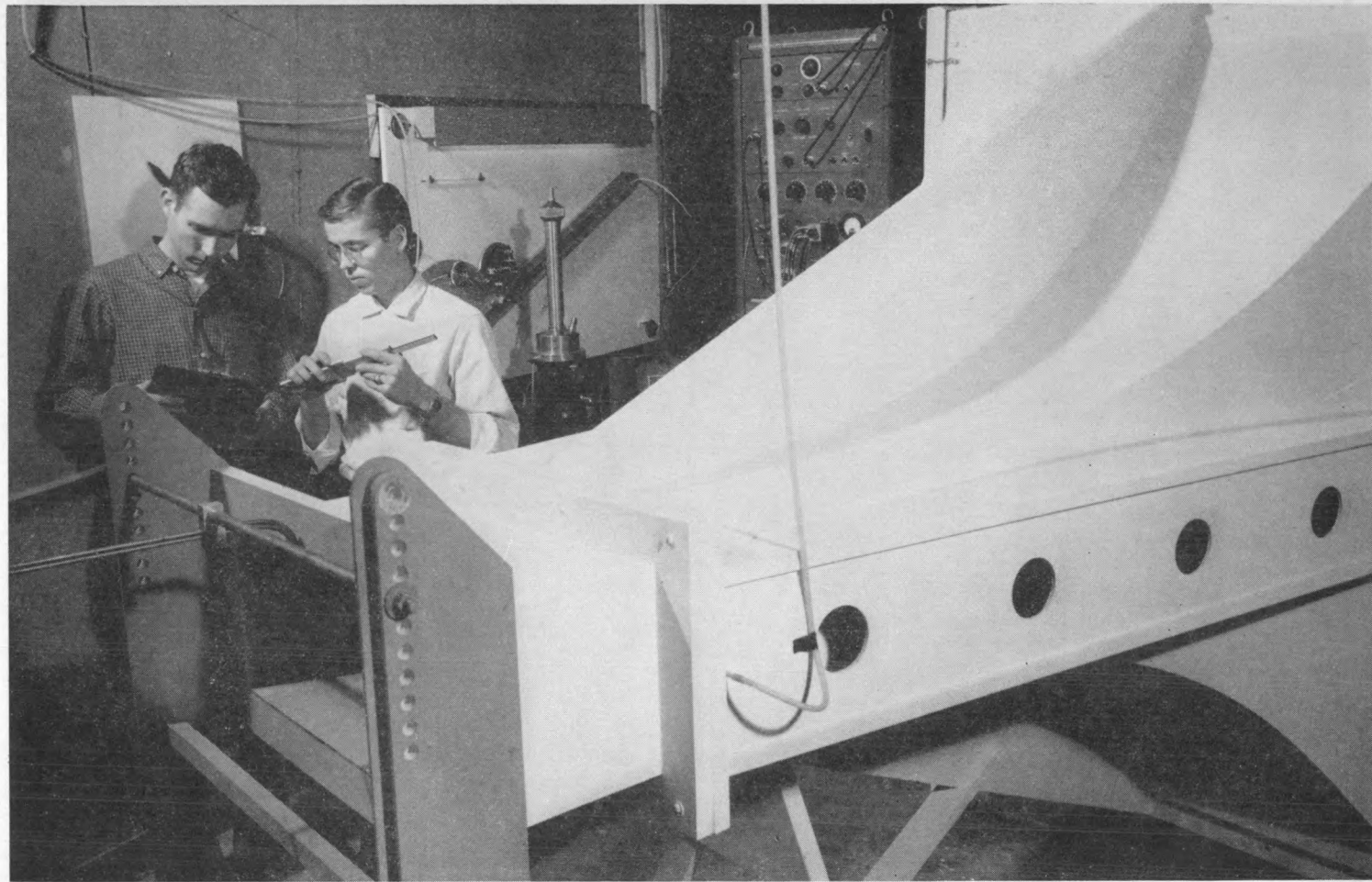
2. A minimum of 18 credits in metallurgical engineering selected from the following list of courses: 5745, 6120, 6221, 6223, 6224, 6352, 6371, 6602, 6841, 6851, 6862, 6953-4-5-6.

A student transferring from another school, after consultation with the faculty, may find it advisable to include in his plan of study certain undergraduate courses in metallurgical engineering or portions thereof, for which he will not receive advanced credit.

3. A minimum of 18 credit hours of elected courses, of which 9 may be nontechnical; courses in the basic physical sciences or in metallurgical engineering in excess of the minimum requirements are considered electives for the purpose of meeting this requirement. All elective courses must be approved by the student's adviser and the Graduate Committee of the School.

SPECIALIZED TRAINING...A student may select his program within the above framework of required and elective courses to provide for specialized training in business administration or in the application of metals to specific industries, such as the chemical or nuclear power industries, as well as in other fields.





THE GRADUATE SCHOOL OF AERONAUTICAL ENGINEERING

THE PRIMARY objective of this School is the training of selected engineering and science graduates in the scientific aspects of aeronautics. This training is intended especially to prepare the students to carry out research and development engineering in the aeronautical and related industries and in aeronautical scientific institutions.

To this end, students are admitted to this School who have demonstrated, in their undergraduate careers, more than average abilities in analytical subjects, and who have shown adequate promise of carrying on graduate study successfully.

In the aeronautical engineering program, considerable emphasis is placed upon original research, both theoretical and experimental. Through the academic year, close contact is maintained between the Graduate School at the University and the Cornell Aeronautical Laboratory in Buffalo, N.Y. In addition, certain periods of employment at the Laboratory are offered to aeronautical engineering students—usually during their summer vacations. Students are urged to take advantage of such employment, if it is available. It is also possible that certain experimental equipment of the Laboratory will occasionally be available to graduate students in connection with their original research.

The Graduate School of Aeronautical Engineering is equipped with a fluid-mechanics laboratory on the campus in Ithaca for fundamental scientific research in fluid mechanics, aerodynamics, and gasdynamics.

ADMISSION

Application for admission to the Graduate School of Aeronautical Engineering as a candidate for the degree M.Aero.E. should be made directly to the Director of the Graduate School of Aeronautical Engineering, College of Engineering, Cornell University. A special application blank for this purpose can be obtained from the office of the Director. It should be sent to the Director of the Graduate School of Aeronautical Engineering.

The degree M.Aero.E. is awarded under the jurisdiction of the College of Engineering, and therefore candidates for this degree do not register in the Graduate School of the University.

Data from this cascade wind tunnel are important in the preliminary design of jet and turboprop aircraft engines.

Students who desire to work for the degree Ph.D. with aeronautical engineering as their major subject must be admitted to the Graduate School of the University in the usual manner. They should make application to the Dean of the Graduate School, using the application blank for admission to the Graduate School.

CURRICULUM

The aeronautical engineering curriculum is planned to accomplish the broad objectives stated above. Courses of study are provided leading to the degree of Master of Aeronautical Engineering and to the degree of Doctor of Philosophy with aeronautical engineering as the major subject.

STUDY LEADING TO THE DEGREE OF M.AERO.E.

This program of aeronautical engineering studies is applicable to much of the standard engineering work in the aeronautical industry, but beyond that it is planned to increase the student's facility in the use of the basic sciences in aeronautical engineering and to stimulate growth in the performance of independent research and development work. Because the progress in this field is so extremely rapid, it is an essential objective of this program to go beyond the study of present-day practices and techniques and to prepare the student in the fundamental background and analytical methods that can be adapted to future development.

(1) *THE CURRICULUM REQUIREMENT* for the degree M.Aero.E. is the successful passing of a series of courses or examinations in these subjects. The list of subjects reproduced below constitutes a standard of accomplishment for the M.Aero.E. candidate, but the faculty will modify the list to suit the needs, interests, and background of each individual candidate. Sufficient course offerings are available to permit candidates to study in any of three areas of aeronautical engineering: (1) aerodynamics, (2) gasdynamics (aerophysics), (3) aeronautical structures. Active research in all three areas is being carried out in the School.

Although the standard list of required subjects is such as ordinarily to occupy (together with the thesis) four terms of graduate study, the residence requirement has been set at one year (two terms), so that students who enter the School with exceptional preparation, or are able otherwise to pass the required examinations, may be able to qualify for the degree in one year.

When the student desires to satisfy a requirement by examination (rather than by passing a course), he should request the faculty of the School to schedule such an examination.

It is suggested that each candidate supplement his required program of courses, e.g., the standard list below, by additional courses either in aeronautical engineering or in other fields of study, so as to result in a balanced program of twelve to sixteen credit hours per term.

(2) *AN ACCEPTABLE MASTER'S THESIS*, based upon original research, is required of each candidate for the M.Aero.E.

(3) *M.AERO.E. CANDIDATES MUST PASS A FINAL EXAMINATION*, either oral or both oral and written, administered by the faculty of Aeronautical Engineering. The faculty will frequently invite other members of the University staff to attend and to participate in such examinations.

STANDARD LIST OF REQUIRED SUBJECTS FOR M.AERO.E.

	CREDIT HOURS
Mathematics 611 and 612, Higher Calculus for Engineers and Physicists.....	6
or	
Engineering 1170 and 1171, Advanced Mechanics	6
Engineering 7101, Mechanics of Airplanes	3
Engineering 7102, Mechanics of Airplanes	3
or	
Engineering 4991, Electronic Engineering	3
Engineering 7203 and 7204, Gasdynamics	6
Engineering 7301, Theoretical Aerodynamics I	3
Engineering 7403 and 7404, Airplane Design	2
Engineering 7405, Aero-Elastic Problems	3
Electives chosen from List A below	12

ELECTIVES: LIST A

Engineering 7206, Special Topics in Physical Gasdynamics	2
Engineering 7302, Theoretical Aerodynamics II (Wing Theory)	3
Engineering 7303, Theoretical Aerodynamics III (Compressible Fluids)	3
Engineering 7304, Theoretical Aerodynamics IV (Viscous Fluids).....	3
Engineering 7306, Theory of Propellers and Rotors	1
Engineering 1162, Mechanics of Vibration	3
Engineering 1163, 1164, Applied Elasticity	3, 3
Engineering 1172, Selected Topics in Engineering Mechanics	(arranged)
Engineering 1175, 1176, Introduction to Nonlinear Mechanics	3, 3
Engineering 1272, Selected Topics in Engineering Materials	(arranged)
Engineering 2711, Buckling of Structures	3
Engineering 2719, Engineering Plasticity	2
Engineering 3652, Combustion Theory	3
Mathematics 621,2, Mathematical Methods in Physics	4, 4
Mathematics 641,2, Partial Differential Equations	3, 3
Physics 242, Analytical Mechanics	3
Physics 243,4, Atomic and Molecular Physics	6
Physics 254, Electronic Properties of Solids and Liquids	3
Physics 380, Special Laboratory Work	(arranged)
Physics 475, Theoretical Mechanics	3

STUDY LEADING TO THE DEGREE OF Ph.D.

Students will be admitted to candidacy for the degree of Ph.D. as set forth in the current *Announcement of the Graduate School*. General requirements such as residence, major and minor subjects, requirements in foreign languages, qualifying examinations, and thesis are also explained there. Each candidate is required to complete a schedule of courses acceptable to his Special Committee, as explained in the *Announcement*.

PREPARATION FOR GRADUATE STUDY

The Graduate School of Aeronautical Engineering will admit students holding baccalaureate degrees in any branch of engineering, physics, or mathematics, provided that their undergraduate scholastic records are such as to indicate ability to handle graduate study. The Cornell courses of study in engineering physics, mechanical engineering, and electrical engineering are especially recommended to students who expect to enter this School after graduation.

All students who expect to enter the Graduate School of Aeronautical Engineering should be sure that their programs include the following courses, or their equivalents:

Mathematics 201	Differential Equations
or	
Engineering 1155	Applied Engineering Mathematics
Engineering 1151, 1152	Mechanics
Engineering 1153	Strength of Materials
Engineering 3630	Thermodynamics

Deficiencies in these subjects must be made up during the first year in the School.

It will be possible for Cornell students in the five-year undergraduate programs to complete the requirements for the degree M.Aero.E. in one year of graduate study instead of the normal two years, if they complete a sufficient number of the required graduate courses as electives in their undergraduate programs. The following courses are recommended for this purpose:

Engineering 7101, 7102	Mechanics of Airplanes
Engineering 7203	Aerodynamics of Power Plants
Mathematics 611, 612	Higher Calculus for Engineers and Physicists
or	
Mathematics 621, 622	Mathematical Methods in Physics
Engineering 7204	Gasdynamics
Engineering 7403, 7404	Airplane Design
Engineering 1170, 1171	Advanced Mechanics

Engineering 1162

Physics 242

Physics 243, 244

Mechanics of Vibration

Analytical Mechanics

Atomic, Molecular, and Nuclear Physics

To be admitted to graduate courses, an undergraduate student must
(1) be a regularly enrolled student in at least the seventh term of one of the engineering, physics, or mathematics curricula at Cornell University.

(2) show promise, by his previous scholastic record or otherwise, of ability satisfactorily to pursue advanced study and research, and

(3) have his admission to the courses recommended by the Director of the Graduate School of Aeronautical Engineering (or the chairman of the department concerned) and approved by the Dean of the College of Engineering.



DEPARTMENT OF ENGINEERING PHYSICS

OBJECTIVES

THE DEPARTMENT of Engineering Physics is a new department constituted so as to provide a type of education and training which will effectively bridge the gap between that of the basic sciences and that of conventional engineering practice. The general aim is to prepare students for a prospective career in technical research and advanced engineering development. As a result of the expanding technological activities in the country, the industrial research laboratories and engineering development laboratories are in urgent need of graduates with the vigorous and exacting course of study which the curriculum of this department provides.

FACULTY

The administrative arrangement of the Department is such that the faculty of the Department includes members of the science departments of the College of Arts and Sciences and members of the several schools of engineering in the College of Engineering who are particularly interested in the objectives of the Department.

LABORATORY FACILITIES

The Department of Engineering Physics has a fully equipped laboratory of electron microscopy, including three large research type electron microscopes and equipment for research both on the instrument itself and on applications to problems in physics, chemistry, biology, and engineering materials. Facilities are also available for study in applied electron optics.

The Department also maintains a laboratory with much special equipment for the study of the elastic properties of single metal crystals, of elastometers, plastics, and similar materials, and of other phenomena related to the physics of the solid state.

Recently, a laboratory of nuclear measurements has been established as part of the nuclear technology program. In addition to a nuclear sub-critical assembly containing two and one-half tons of natural uranium, the laboratory is well equipped with Geiger counters and scalars, neutron sources, linear amplifiers, and so on, for experimental

work associated with the rapidly expanding field of applied nuclear physics.

In addition, students carrying out their project study have access to the other laboratories of the College of Engineering and to those of the College of Arts and Sciences as may be desirable.

PROGRAM OF STUDIES

The curriculum leading to the degree of Bachelor of Engineering Physics covers intensive study over a five-year period. The course of study is designed to combine the broad, basic, scientific and analytical training of the physicist with the knowledge of the properties of materials and the technological principles of the engineer. The subject matter falls into three main categories: fundamental sciences, namely, mathematics, physics, and chemistry; the properties and treatment of material; and engineering practice.

For training in engineering research and development, the student terminates the course by carrying out a semi-research project in a special field of his own choice, under the direction of a faculty member who is an authority in the selected field. There are a great variety of these special fields in physical science and engineering. They include topics in electron physics, atomic and nuclear physics, physical optics, electron optics, and applications including electron microscopy, X-rays and crystal structure, spectroscopy, engineering electronics, communications, electrical machinery, servomechanisms, ultra high-frequency generation and propagation, circuit analysis, elasticity and stress analyses, properties of materials, engineering mechanics, physical metallurgy, thermodynamics and heat transfer, aerodynamics, airplane structure, etc.

ELECTIVE COURSES

SCIENTIFIC AND TECHNICAL ELECTIVES. . . Considerable flexibility in the technical courses is provided in the last few terms of the curriculum to allow the student to advance in some technical fields beyond the level provided by the required courses as his interest in such fields develops. To permit this, eighteen hours are provided to cover the semi-research project and the technical electives which may be selected, with the permission of the student's adviser, from the following subjects: physics, mathematics, chemistry, physical metallurgy, advanced mechanics and elasticity, engineering materials, fluid mechanics, aerodynamics, heat power, communications, industrial electronics, servomechanism theory, ultra high frequency. The choice will depend largely on the student's particular ability or interest.

By suitable selection of technical electives during his last two years of candidacy for the B.Eng.Phys. degree, the qualified student may

obtain an unusually sound and well rounded education preparing him for a career in one of the many specialized fields of engineering. Here are two examples.

Aeronautical Engineering. A properly qualified student may elect courses given in the Graduate School of Aeronautical Engineering and thus obtain an excellent preparation in aeronautical engineering at the undergraduate level. Also, this procedure will shorten the time required to complete the requirements for the M.Aero.E. degree if the student wishes to continue study in that field. Details of this arrangement are described on page 78.

Nuclear Technology. It is possible to choose electives so as to provide a well rounded and extensive education for a career in the nuclear energy field or in nuclear reactor power developments. Courses in reactor physics, in nuclear measurements, in advanced heat transfer, and in physics of solids underlying radiation damage problems are available.

Members of the faculty will assist the student in planning a special program in his particular field of interest.

NONTECHNICAL ELECTIVES. . . The curriculum provides for a minimum of thirty hours of liberal courses. Of these, twelve hours are specified as Introductory English and Modern Foreign Languages, and eighteen hours are to be chosen by the student in consultation with his adviser.

These electives may be chosen from the following subjects: astronomy, biology, botany, the classics, economics, English, fine arts, government, history, industrial and labor relations, literature, music appreciation, philosophy, psychology, sociology, speech. The opportunity thus afforded for contact with the broader phases of education offered by the University as a whole assists in expanding the student's mental horizon and in developing him as a well-rounded citizen.

Students who pass the proficiency examination of the Department of Modern Languages and do not wish to continue the study of a language shall substitute six hours of other liberal electives in place of the language requirement. Students who wish to continue the modern language studied in high school will be asked to take a placement examination at the University unless they have taken the College Board Achievement Test in that language. Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

ADDITIONAL ELECTIVES. . . In addition, a maximum of nine hours of free electives is provided which may be chosen from any courses in the University which are open to the student, except, however, that

not more than six credit hours toward the baccalaureate degree will be allowed in advanced military science and tactics or in naval science.

CLASS ADVISERS

Members of each entering class in the engineering physics curriculum are assigned to an experienced faculty member who will counsel and supervise each student in matters connected with choice of elective courses, registration, scholarship, and other matters of importance encountered during the student's entire college career. The personal relationship between the adviser and the student and the adviser's intimate knowledge of the student's academic performance can be of great help to the student in obtaining the best results from his university training.

SCHOLASTIC REQUIREMENTS

A student enrolled in the engineering physics curriculum is expected to maintain the following minimum scholastic requirements:

- (1) receive a passing grade in every course for which he is registered,
- (2) maintain each term a weighted average of at least 75%,
- (3) exhibit natural aptitude and competence in the basic subject matter of the curriculum.

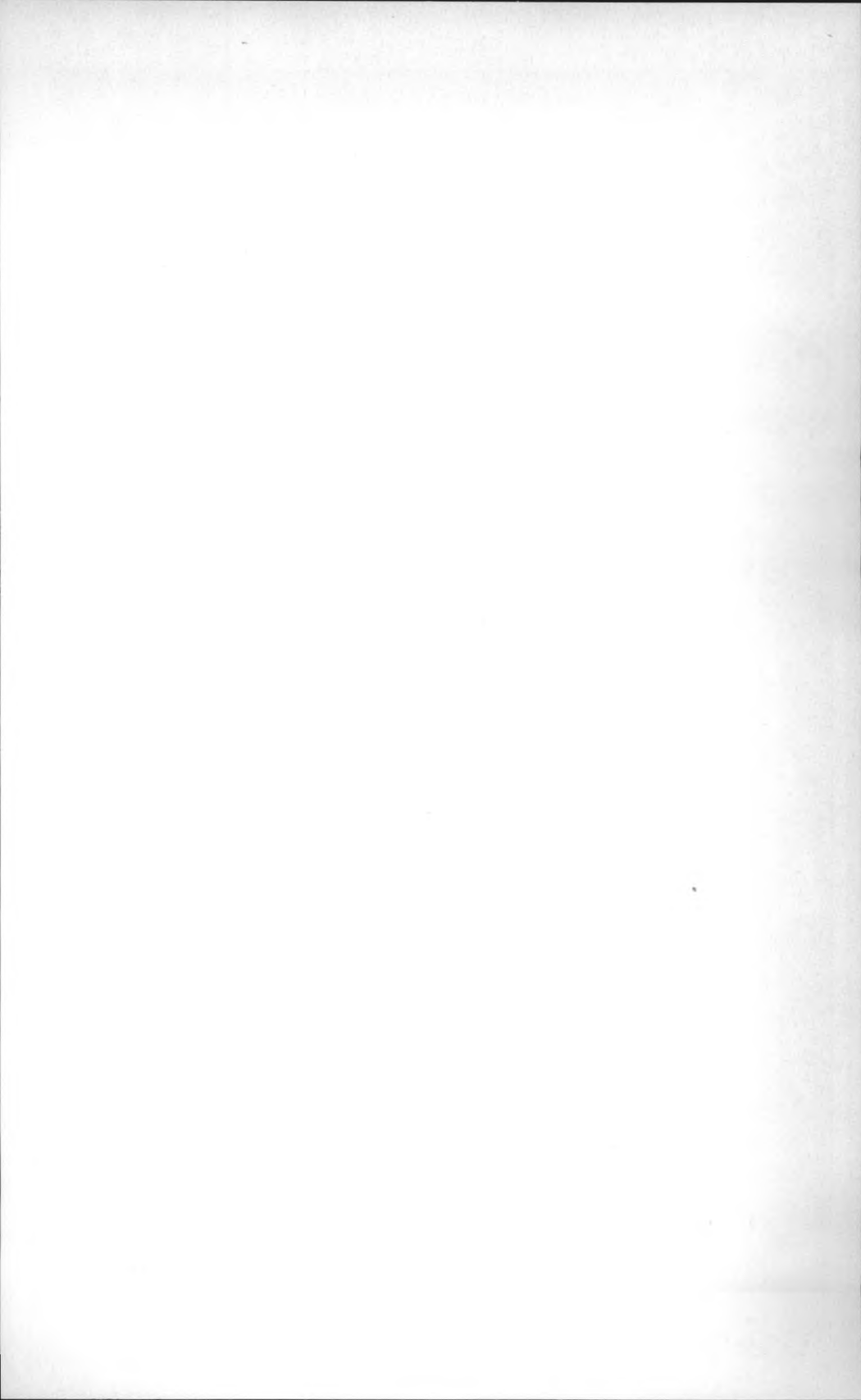
A student failing to satisfy these requirements may be put on probation or refused permission to continue his studies in the Department.

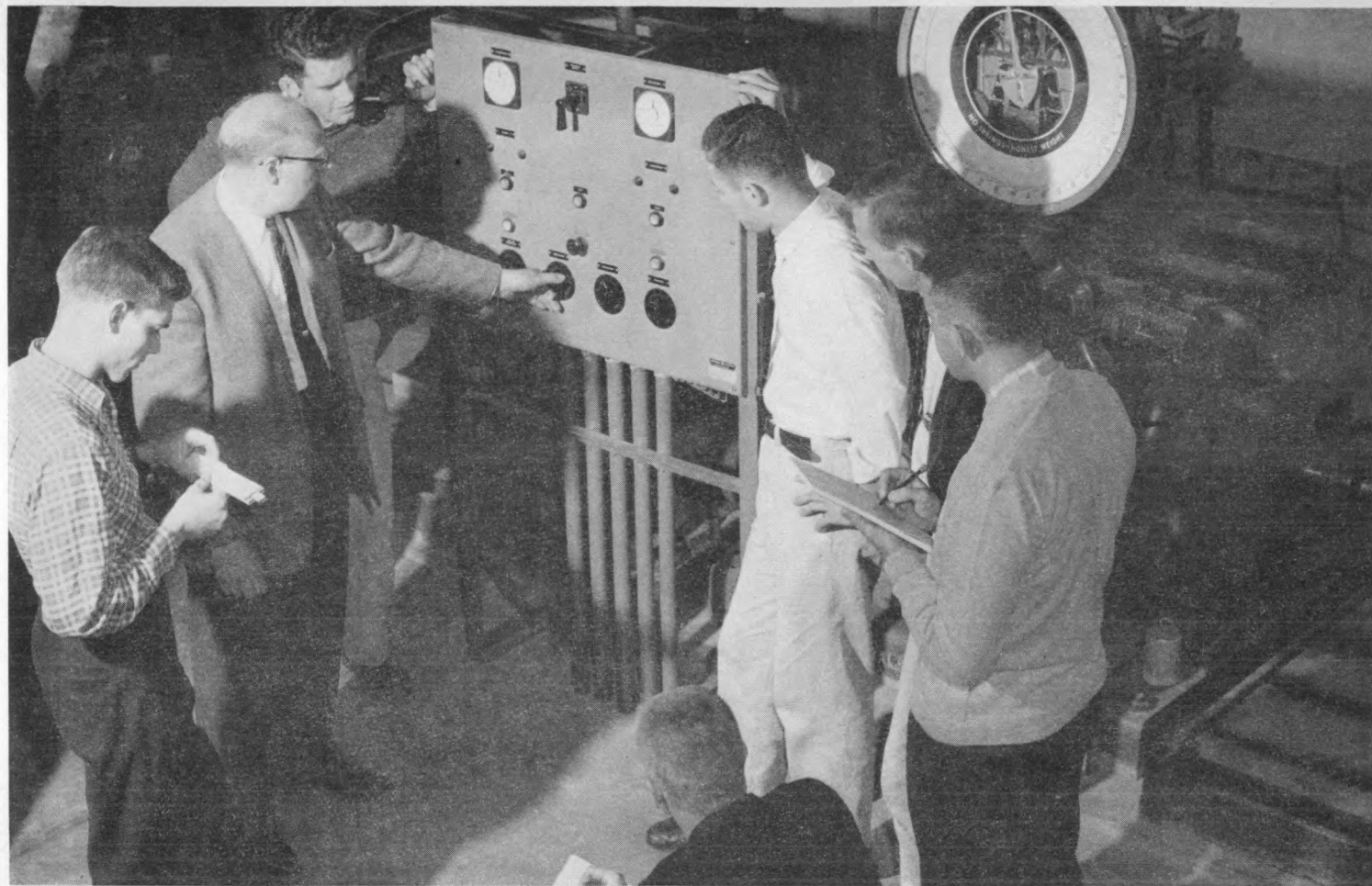
THE ENGINEERING PHYSICS CURRICULUM

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161 or 181, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Chemistry	3	3	2½
	English 111, Introductory Course	3	3	0
	Engineering 3117, Drawing and Descriptive Geometry	2	0	5
	Liberal elective	3	3	0
	Total	17		
TERM 2	Mathematics 162 or 182, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Chemistry 106, General Chemistry	3	2	3
	English 112, Introductory Course	3	3	0
	Engineering 3118, Drawing and Descriptive Geometry	2	0	5
	Engineering 3403, Fundamentals of Machine Tools	1	1	1½
	Elective	3		
	Total	18		

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 3	Mathematics 163 or 183, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Engineering 1151, Statics	3	3	0
	A modern foreign language	6	2	6
	Engineering 6110, Casting, Working and Welding of Metals	2	1	2
	Total	17		
TERM 4	Mathematics 201, Elementary Differential Equations	3	3	0
	Physics 118, Electricity, Magnetism, and Light ...	3	3	2½
	Chemistry 402, Introduction to Physical Chemistry	3	3	0
	Engineering 1152, Dynamics	3	3	0
	Engineering 4983, Basic Electrical Engineering..	4	3	2½
	Total	16		
In addition to these courses, students must satisfy the University's requirements in military training and physical education for the first four terms.				
TERM 5	Mathematics 613, Methods of Applied Mathematics	3	3	0
	Physics 225, Electricity and Magnetism	3	3	0
	Engineering 8121, Thermodynamics and Kinetic Theory	3	3	0
	Engineering 4116, Electric-Circuit Laboratory ...	3	1	3
	Engineering 1153, Mechanics of Materials	3	2	2½
	Elective	3		
	Total	18		
TERM 6	Mathematics 614, Methods of Applied Mathematics	3	3	0
	Physics 242, Analytical Mechanics	3	3	0
	Engineering 8122, Thermodynamics and Kinetic Theory	3	3	0
	Engineering 4121, Electron Tubes and Circuits ..	4	2	5
	Elective	3		
	Total	16		
TERM 7	Mathematics 615, Methods of Applied Mathematics	3	3	0
	Physics 243, Atomic and Molecular Physics	3	3	0
	Engineering 1201, Engineering Materials	4	3	2½
	Engineering 4122, Electronic Circuit Elements...	4	2	5
	Elective	3		
	Total	17		

		CONTACT HOURS		
		CREDIT	LEC.	LAB.
		HOURS	REC.	COMP.
TERM 8	Mathematics 616, Methods of Applied			
	Mathematics	3	3	0
	Physics 254, Electronic Properties of Solids and			
	Liquids	3	3	0
	Physics 210, Advanced Laboratory	3	0	5
	Chemistry 416, Chemical Bonding and Physical			
	Properties of Organic Molecules	3	3	0
	Elective	3		
	Total	15		
TERM 9	Physics 210, Advanced Laboratory	3	0	5
	Engineering 8252, Selected Topics in Physics of			
	Engineering Materials	3	3	0
	Engineering 8051, Project	3		
	Electives	9		
	Total	18		
TERM 10	Physics 258, Mechanics of Continuum	3	3	0
	Engineering 8052, Project	3		
	Electives	12		
	Total	18		





AGRICULTURAL ENGINEERING

A JOINT program administered by the Colleges of Agriculture and Engineering leads to the degree of Bachelor of Agricultural Engineering. Students in this curriculum register in the College of Agriculture during the first four years but take courses in the Colleges of Engineering, Arts and Sciences, and Agriculture. Registration for the fifth and final year is in the College of Engineering, which grants the degree.

The purpose of this curriculum is to train engineers for service in the agricultural industry in such fields as power and machinery, structures, soil and water engineering, electrification, and the processing and handling of agricultural products. Modern mechanized agriculture is dependent upon the products and services of many industries and organizations to supply food and fiber to an ever-increasing population.

Graduates in agricultural engineering find ready employment in the manufacturing industry, in the food processing and marketing industry, in public service utilities, in consulting and farm-management services, and many others. Educational institutions and governmental agencies have continued need for research engineers in investigations related to irrigation, to water conservation and control, to soil management, to machinery for handling new and specialized crops, and in problems related to structures and to labor efficiency in the production and management of crops and livestock. Colleges and universities must also continue to provide teachers for training new engineers.

FACILITIES

The Department of Agricultural Engineering moved into Riley-Robb Hall, a new and excellently equipped building, in 1956. This building provides complete facilities for teaching, extension, and research programs. The laboratories provide adequate space and the latest equipment for teaching in all fields of agricultural engineering and food technology.

ADMISSION REQUIREMENTS

Requirements for entrance to this curriculum are the same as those for mechanical, civil, and electrical engineering. Since, however, it is the purpose of this curriculum to train engineers for agriculture, care-

ful attention will be given to evidence of interest in and background for the work on the part of applicants.

OUTLINE OF INSTRUCTION

The curriculum leading to the degree of Bachelor of Agricultural Engineering requires five years of study. Subject matter is drawn from five basic fields of study:

1. Basic science (mathematics, chemistry, physics, biology, bacteriology, geology)
2. Engineering science (mechanics, property of materials, thermodynamics, heat transfer, electrical theory)
3. Engineering application (structural design, hydraulics, surveying, power, machinery design, water control and management)
4. Agriculture (soils, field crops, livestock feeding, farm management)
5. General studies (English, history, public speaking, economics)

Students in this curriculum are required to meet the farm-practice requirement of the College of Agriculture (see the *Announcement of the New York State College of Agriculture*).

SCHOLASTIC REQUIREMENTS

To remain in good standing, a student must have a weighted average for the term of 70 or above. If the weighted average is 60 or higher, but less than 70, the student will be placed on probation. A student will be dropped from the program if a third consecutive term of probation is indicated or if the weighted average is below 60. In all cases, the student may appeal an action by presenting new information to the Joint Faculty Committee.

CURRICULUM (B.Agr.E.)

(For a complete description of the courses in agriculture, see the *Announcement of the College of Agriculture*.)

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and			
	Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Inorganic Chemistry....	3	2	3
	English 111, Introductory course	3	3	0
	Engineering 3111, Drawing and Descriptive			
	Geometry	3	1	5
	Agriculture 1, Orientation	1	1	0
	Total	16		

		CONTACT HOURS		
TERM 2		CREDIT	LEC.	LAB.
		HOURS	REC.	COMP.
	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Chemistry 106, General Inorganic Chemistry	3	2	3
	English 112, Introductory Course	3	3	0
	Engineering 3112, Mechanical Drafting	3	1	5
	Agr. Engineering 2, Introduction to Agricultural Engineering	2	2	0
	Total	17		

In addition to these courses, all freshmen must satisfy the University requirements in military training and physical education.

Farm practice is required. See the *Announcement of the College of Agriculture*.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Chemistry 301, Organic Chemistry	2	2	0
	Engineering 1151, Mechanics—Statics	3	3	0
	Biology 1, General Biology	3	2	2½
	Geology 115, Elementary Geology	3	2	2½
	Total	17		
TERM 4	Physics 118, Electronics and Optics	3	3	2½
	Chemistry 402, Physical Chemistry	2	2	0
	Engineering 1152, Mechanics—Dynamics	3	3	0
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 2132, Surveying	3	3	2½
	Biology 1, General Biology	3	2	2½
	Total	17		

In addition to these courses, all sophomores must satisfy the University requirements in military training and physical education.

TERM 5	Engineering 1241, Materials of Construction	3	2	2½
	Engineering 2301, Elementary Fluid Mechanics ..	3	3	0
	Engineering 2731, Elements of Structural Engineering I	3	2	2½
	Agronomy 1, Nature and Properties of Soils	5	5	2½
	Engineering 1155, Applied Mathematics	3	3	0
	Total	17		

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 6	Engineering 3341, Machine Design	4	3	2½
	Engineering 1242, Materials of Construction	3	2	2½
	Engineering 2302, Applied Hydraulics and Hydrology	3	2	2½
	Agricultural Bacteriology 3	3	3	0
	Agricultural Bacteriology Laboratory 5	1	0	4
	Engineering 2732, Elements of Structural Engineering II	3	2	2½
	Total	17		
TERM 7	Engineering 2715, Reinforced Concrete Design ...	3	2	2½
	Engineering 3601, Thermodynamics	3	3	0
	Agronomy 11, Production of Field Crops	4	3	2½
	Social science elective	3	3	0
	Animal Husbandry 10, Livestock Feeding	4	3	2½
	Total	17		
TERM 8	Engineering 3602, Engineering Thermodynamics	3	2	2½
	Agr. Engineering 221, Soils and Water Engineering	3	2	2½
	Agr. Economics 102, Farm Management	5	3	3
	Agr. Engineering 231, Farm Buildings Design	3	2	2½
	Social Science Elective (preferably Economics) ...	3	3	0
	Total	17		
Summer: Six-week term. No. 206, Field Problems in Agricultural Engineering. Credit 6 hours.				
TERM 9	Engineering 3605, Heat Transfer	3	2	2½
	Engineering 4931, Electrical Engineering	3	2	2½
	Extension Teaching 101, Oral and Written Exp.	2	2	0
	Agr. Engineering 202, Farm Power	3	2	2½
	Agr. Engineering 253, Special Topics	1	Arr.	Arr.
	Elective	6	Arr.	Arr.
	Total	18		
TERM 10	Engineering 3609, Refrigeration and Air Conditioning	3	3	0
	Engineering 4932, Electrical Engineering	3	2	2½
	Agr. Engineering 203, Agricultural Machinery Design	3	2	2½
	Agr. Engineering 253, Special Topics	1	Arr.	Arr.
	Elective	9	Arr.	Arr.
	Total	19		
Total for Ten Terms		178		

DESCRIPTION OF COURSES

THE COURSES listed in the preceding curricula are described in the sections following. Courses are described under the heading of the school or college in which they are offered. Courses in chemistry, English, mathematics, physics, and certain courses in economics are offered by the College of Arts and Sciences. Courses in military training and physical education, under the direct supervision of the University as a whole, are listed in a general section.

The courses designated by four digit numbers are offered by the College of Engineering. The first digit represents the school or department. Descriptions of courses will be found in the section of this Announcement as follows:

- | | |
|--|------------------------------|
| 1. Engineering Mechanics and Materials | 5. Chemical Engineering |
| 2. Civil Engineering | 6. Metallurgical Engineering |
| 3. Mechanical Engineering | 7. Aeronautical Engineering |
| 4. Electrical Engineering | 8. Engineering Physics |

General courses of instruction required by some or all of the schools within the College of Engineering but given in other colleges of the University are described on pages 129-137, inclusive.

For courses in other colleges not described here, to be taken as electives, see the Announcement of the appropriate college.

ENGINEERING MECHANICS AND MATERIALS

Courses described in this section are given by the Department of Engineering Mechanics and Materials. They constitute a major part of the stem of basic engineering science prescribed for all engineering students and are directed toward the development of fundamental background for application to all phases of engineering work.

Advanced and graduate courses in these fields are also included in this section.

MESSRS. BLOCK, CONWAY, CRANCH, CUYKENDALL, GOFF, JEFFREY, MASON, MITCHELL, MOYNIHAN, PERKINS, RUOFF, SACK, SLATE, STUART, and WIEGANDT.

1134. *MECHANICS OF ENGINEERING—STRENGTH OF MATERIALS*. Credit 3 hrs. 1 Lect. 2 Rec. Prereq., 1153. Elastic curves, safe loads, columns, flexure of beams. Problems showing the application of engineering design.

1145. *APPLIED ENGINEERING MATHEMATICS*. Credit 3 hrs. 1 Lect. 2 Rec.

Prereq., Mathematics 163. Elementary ordinary and partial differential equations, Fourier series and engineering applications in civil engineering fields.

1151. *MECHANICS OF ENGINEERING—STATICS*. Credit 3 hrs. 1 Lect. 2 Rec. Prereq., Physics 115 and parallel registration in Mathematics 163. The principles of statics of particles, chains, and rigid bodies. Equilibrium, friction, centroids, moments and products of inertia, virtual displacements, graphical methods, three dimensional trusses and frames. Vector methods.

1152. *MECHANICS OF ENGINEERING—DYNAMICS*. Credit 3 hrs. 1 Lect. 2 Rec. Prereq., 1151 and 1155 or 1156, or parallel registration in Mathematics 607. The principles of dynamics of particles and rigid bodies. Rectilinear, curvilinear, rotational, and general plane motion of rigid bodies. Vector methods. (The section of this course for agricultural and civil engineering students is offered in the spring term only and does not require 1155 as a prerequisite.)

1153. *MECHANICS OF MATERIALS*. Credit 3 hrs. 1 Lect. 1 Rec. 1 Lab. Prereq., 1151. Stress and strain, tension, compression, and shear, riveted and welded joints, elementary beam theory, combined stresses, columns, strain energy, beams on several supports.

1154. *ADVANCED STRENGTH OF MATERIALS*. Credit 3 hrs. 1 Lect. 2 Rec. Prereq., 1153 and 1155. Strength, stiffness, and stability of machine parts, disks, plates, shells, thick cylinders, straight and curved beams; principal stresses in two and three dimensions; fatigue and theories of failure.

1155. *APPLIED ENGINEERING MATHEMATICS*. Credit 3 hrs. 1 Lect. 2 Rec. Prereq., 1151 and Mathematics 163. The formulation and solution of problems, arising in mechanical engineering, which involve the use of elementary differential equations and Fourier series. Emphasis is placed on numerical as well as analytical methods of solution.

1156. *APPLIED ENGINEERING MATHEMATICS*. Credit 3 hrs. 1 Lect. 2 Rec. Prereq., Mathematics 163. The formulation and solution of problems in chemical engineering involving ordinary and partial differential equations, graphical and numerical methods, and special functions.

1159. *ADVANCED MECHANICS LABORATORY*. Credit 3 hrs. 2-2½ hour Lab. Primarily for graduate students. Analysis and design of experiments; measuring and loading techniques; SR-4 strain gages; vibration analysis of rods, plates and shells. (Not given in 1958-1959.)

1162. *MECHANICS OF VIBRATION*. Credit 3 hrs. 3 Lect. Fall or spring as announced. For graduates and qualified undergraduates. Vibration of lumped and continuous systems; damping; free and forced motion; resonance; vibration isolation; self-excited vibration.

1163, 1164. *APPLIED ELASTICITY*. Continuing two terms. Credit 3 hrs. 3 Lect. For graduates and qualified undergraduates; spring and fall terms respectively. Three lectures per week each term. General analysis of stress and strain; Airy's stress function; Fourier and strain energy methods; torsion; thick cylinders; disks; beams on elastic foundations; curved bars; Castigliano's theorem.

1165. *MATHEMATICAL ELASTICITY*. Credit 3 hrs. 3 Lect. Spring term. Prereq., 1163, 1164. Graduate students. Mathematical theory of elasticity using tensor development; plates and shells; finite deformation; complex variable techniques—Muskhelishvili's method.

1170. *ADVANCED MECHANICS*. Credit 3 hrs. Fall term. 3 Rec. Prereq., 1155. The formulation and solution of problems in engineering by vector methods, Lagrange's equations, generalized coordinates, Fourier series. Conservative systems.

1171. *ADVANCED MECHANICS*. Credit 3 hrs. Spring term. 3 Rec. Continuation of 1170. Nonconservative systems, energy methods, impact loads, operational methods.

1172. *SELECTED TOPICS IN ENGINEERING MECHANICS*. Credit as arranged, any term. Qualified students wishing to do work in any field of engineering mechanics should register for this course after consultation with the Department. Students will work with appropriate members of the staff in the chosen field. Typical areas of work include theory of elastic stability, theory of plates and shells, rocket theory and design, and wave propagation.

1175. *INTRODUCTION TO NONLINEAR MECHANICS*. Credit 3 hrs. 3 Rec. Spring term. A study of the methods of analysis of the nonlinear electrical and mechanical systems frequently encountered in practice, including criteria for stability and a comparison between linear and nonlinear methods. Emphasis will be placed upon the discussion of a number of problems rather than upon the coverage of a broad field.

1176. *INTRODUCTION TO NONLINEAR MECHANICS II*. Credit 3 hrs. Fall term. 3 Rec. Prereq., 1175, or permission of the instructor. Continuation of 1175. Nonlinear ordinary differential equations of second and higher order. Introduction to nonlinear partial differential equations. Examples are taken from electrical engineering and the mechanics of continua.

1180. *ADVANCED ENGINEERING MATHEMATICS*. Credit 3 hrs. Fall term. 3 Lect. Prereq., 1155 or equivalent. Linear differential equations, Laplace transforms, infinite series, transcendental equations, orthogonal functions, calculus of variations, partial differential equations. Special applications in mechanical and civil engineering and mechanics.

1198, 1199. *PROJECT*. Credit 3 hrs. each term. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of engineering mechanics.

1201. *ENGINEERING MATERIALS*. Credit 4 hrs. 3 Lect. 1 Lab. Prereq., 1153 and Chemistry 402. A lecture course treating the physical and electrical properties of engineering materials with special emphasis on the relation of these properties to the structure of the materials and to their forming, working, heat treatment, etc.

1202. *ADVANCED ENGINEERING MATERIALS*. Credit 3 hrs. Fall term. Primarily for fifth year students in engineering physics; others with consent of instructor. Discussion of a number of special topics in the field of engineering materials, such as plastic and rheological properties; dielectric and magnetic behavior; semi-conductors, etc. Emphasis is given to the interpretation of the phenomena in light of modern theories in physics of solids and liquids; current literature is included in the assignments. (See Engineering Physics.)

1212. *ENGINEERING MATERIALS*. Credit 3 hrs. 1 Lect. 2 Lab. Prereq., 1241. Should be preceded by or taken concurrently with 2715. Timber, cement, concrete aggregates, concrete, elemental concrete structural members, lime, gypsum. Design of concrete mixes, acceptability of materials, and physico-chemical properties of materials. Extensive laboratory testing and report writing.

1216. *STRUCTURE AND PROPERTIES OF MATTER*. Credit 2 hrs. Fall term. 2 Lect. Open to graduate students in engineering or the physical sciences or by consent of instructor. Internal structure of materials ranging from the amorphous to the crystalline state. Correlation of the internal structures of materials with their physical and mechanical properties, primarily on a qualitative basis. Applications to metals and other engineering materials.

1217. *ADVANCED PLAIN CONCRETE*. Credit 2 hrs. Spring term. 2 Lect. Prereq.,

1212 or equivalent. Topics in the field of concrete, such as history of cementing materials, air-entrainment, light-weight aggregates, petrography, durability, chemical reactions and properties of aggregates. Relationships between internal structure, physical properties, chemical properties and the mechanical properties of interest to the design and construction engineer.

1241. *ENGINEERING MATERIALS*. Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 1153, and Chem. 401 or 402. An introductory lecture-laboratory course. Structure and mechanical properties of metals and alloys. Ferrous metals: carbon steels, cast irons, alloy steels. Nonferrous metals. Wood, plastics, cements and concrete.

1242. *ENGINEERING MATERIALS*. Credit 3 hrs. 2 Lect. 1 Rec. Prereq., 1241. A lecture course making a detailed study of the fundamental structure and mechanical properties of metals and alloys and the effects of hot and cold working. Carbon and low alloy steels in the annealed and heat treated condition. High alloy steels.

1243. *ENGINEERING MATERIALS*. Credit 3 hrs. 1 Lect. 1 Lab. Prereq., 1242. A lecture-laboratory study of the structure and properties of cast irons, nonferrous metals and alloys, special purpose alloys. Corrosion. Nonmetallic materials: plastics, glass, rubber, lubricants.

1252. *APPLICATIONS OF ENGINEERING MATERIALS*. Credit 3 hrs. 2 Lect. 1 Rec. Prereq., 1231. The applications of physical metallurgy to problems in engineering and processing operations, including casting, mechanical working and heat treatment, and the use of ferrous and nonferrous metals and alloys.

1255, 1256. *MATERIALS OF CONSTRUCTION*. Credit 3 hrs. each term. 3 Lect. Prereq. or parallel courses, Physical Chemistry 403, 404. An introductory presentation of the nature, properties, treatment, and applications of the more important metals and alloys, including extractive and physical metallurgy and behavior under service conditions. Nonmetallic materials, including refractories, cement, protective coatings, and plastics, are also discussed.

1272. *SELECTED TOPICS IN ENGINEERING MATERIALS*. Credit as arranged, any term. Qualified students wishing to do work in any field of engineering materials should register for this course after consultation with the Department. Students will work with appropriate members of the staff in the chosen field. Typical areas of work include engineering materials research, advanced concrete, plastic behavior of solids, structure and properties of matter, and physics of engineering materials.

1298, 1299. *PROJECT*. Credit 3 hrs. each term. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of engineering materials.

CIVIL ENGINEERING

DESCRIPTIVE GEOMETRY AND DRAWING

Mr. HEWITT and others.

2001. *DRAWING*. Credit 3 hrs. Fall. A first course of elementary civil engineering drawing, emphasizing the fundamentals of the graphic language as used in engineering. Technical lettering, the use of instruments, orthographic projection, free-hand and technical sketching, working drawings, and charts and graphs. Prints are made of many of the tracings.

2002. *DRAWING*. Credit 3 hrs. Spring. Prereq., 2001 or equivalent. Instruction and drill in the fundamental conceptions of descriptive geometry dealing with the graphic solution of advanced space problems. This course develops a firm grasp of the principles of projection and provides ample training in visualization. Practical

civil engineering problems from the fields of topographic mapping, structural drafting, and cartography are included in the course.

2004. *ADVANCED DRAWING*. Credit 1-3 hrs. Problems in concrete, structural, topographical, highway, and sanitary drafting; engineering drawings, rendered in color, to enable the student to supplement ordinary drawings with artistic representations, so portrayed as to be readily intelligible to persons without technical training.

2005. *CARTOGRAPHY*. Credit 3 hrs. Fall. A study of the field of cartography, with particular attention to the principles of map projections, the conventions, scales, and construction of planimetric, topographic, and chorographic maps from survey notes and data from aerial photographs. A first course to combine photogrammetry and topographic surveying into a practical course on map making and interpretation.

2006. *MAP REPRODUCTION*. Credit 3 hrs. Spring. The preparation of map manuscripts and models for reproduction by both photographic and mechanical methods of duplication. The selection, evaluation, and organization of cartographic material from ground and aerial surveys into map editions will assure the proper procedure to adopt for local circumstances.

SURVEYING

Messrs. LYON, McNAIR, TOOLES, and others.

2111. *ELEMENTARY SURVEYING*. Credit 2 hrs. Spring. 1 Rec. 1 Lab. Use and care of steel tape, level, and transit; note keeping; fundamental surveying methods; measurements of lines, angles, and differences of elevations; areas and plotting.

2112. *ADVANCED SURVEYING*. Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereq., 2111. Elements of topographic, hydrographic, and geodetic surveying; map projections; elements of practical astronomy; city, land, and mine surveying; theory of errors; surveying specifications.

2113. *ROUTE AND AERIAL SURVEYING*. Credit 3 hrs. Fall. 1 Rec. 2 Lab. Prereq., 2111. Theory and practice in photogrammetric methods; theory and practice in staking out route locations involving simple, transition, and vertical curves; earthwork measurements and computations. About one-third of the course is devoted to photogrammetry, one-third to paper reconnaissance, curve theory, and earthwork computations, and one-third to field work associated with route locations.

2114. *SUMMER SURVEY*. (Topographic, Hydrographic, Route, and Geodetic Survey Camp.) Credit 5 hrs. Field and office work six days a week for five weeks. Date to be announced in spring term. Prereq., 2112 and 2113. Practical experience in surveying under field conditions. Extensive topographic survey and corresponding map with emphasis on transit-stadia and plane table-stadia methods. Hydrographic survey and map of Cayuta Lake. Complete route survey including reconnaissance from aerial photographs, preliminary survey, paper location, and staking of the final line. All horizontal and vertical control surveys are executed according to present standards, including base-line taping, triangulation with repeating and direction type optical-reading theodolites, subtense and trig traverse, precise leveling, and altimetry. Astronomic observations for azimuth and position are made and results computed.

2115. *LEAST SQUARES ADJUSTMENT OF OBSERVATIONS*. Credit 3 hrs. Fall. Designed for students desiring to make experimental investigations. Studies are made of the principles of probability; precision of observations, the propagation of errors, and the application of the fundamental principles of least squares to criteria for determining the significance of results; and derivation of empirical formulas.

2116. *LAND SURVEYING*. Credit 3 hrs. 3 Rec. Prereq., consent of instructor. Functions and responsibilities of a land surveyor; deeds and land descriptions; land records and land courts. Study of U. S. Public Land system, metes and bounds, subdivisions, resurveys, cadastral surveys, riparian rights, mineral land surveys, and other land survey systems. Specifications and registration.

2117. *GEODETIC SURVEYING*. Credit 3 hrs. 3 Rec. Prereq., consent of instructor. Consideration of special problems in geodetic surveying; base line; triangulation; traverse; precise leveling; deflection of the plumb line; figure of the earth; determination of gravity; isostasy; magnetic properties of the earth. Subject to arrangement to meet the special needs of students.

2119. *MAP PROJECTIONS*. Credit 3 hrs. The theory of map projections. Construction of projections. Plane coordinate systems.

2120. *VERTICAL CONTROL*. Credit 3 hrs. Prereq., 2112. Lectures, reading, and field work. Principles of establishing a geodetic sea-level datum and of performing barometric, trigonometric, spirit, and electronic leveling. Study of precision altimetry by the single-base, two-base, and leapfrog methods. Determination of economic relationships of vertical control methods to mapping scale especially for photogrammetric mapping.

2121. *ELEMENTS OF PHOTOGRAMMETRY*. Credit 3 hrs. Fall. Prereq., 2113. Lectures, recitation, and laboratory work. Principles and practice of terrestrial and aerial photogrammetric mapping, including planning flights, control surveys, uncontrolled mosaics, radial-line control, simple stereo-plotting instruments, parallax distortions, graphical tilt determination, trimetrogen charting, and economics.

2122. *ADVANCED PHOTOGRAMMETRY*. Credit 3 hrs. Spring. Prereq., 2121 or consent of instructor. Lectures, reading, and laboratory work. An advanced study of photogrammetric principles including controlled mosaics, rectification, graphical, mechanical, and analytical space orientation. Readings and reports from current technical literature. The principles of many photogrammetric plotters are studied together with the economic relation of these instruments to density of field control, office methods, and personnel.

2123. *SURVEYING AND MAPPING INSTRUMENTATION*. Credit 3 hrs. Prereq., 2121. Lectures and assigned reading. Independent study of developments in surveying, mapping, and photogrammetric instruments including a brief historical sketch of instrumentation; optical-reading levels and transits; electronic base line measurement; precision altimeters; sonar equipment; equiangular, odograph, and stereoscopic plotters. Correlation of the principles of physics and mathematics in new measuring instruments and methods.

2131. *ELEMENTS OF SURVEYING*. Credit 1 hr. 1 Lab. Fundamentals of engineering measurements. Appreciation of observations and errors. Principles of recording data. Use of steel tape, level, and transit. Problems of particular interest to students in fields other than civil engineering.

2132. *SURVEYING*. Credit 3 hrs. Spring. 2 Rec. 1 Lab. Fundamentals of engineering measurements. Appreciation of methods of observations and errors. Principles of recording data. Use of steel tape, level, transit, and plane table. Aerial mapping. Emphasis on problems common in agricultural engineering.

2142. *GEODETIC OR PHOTOGRAMMETRIC ENGINEERING RESEARCH*. Prerequisites will depend upon the line of work to be pursued. Special problems in least squares, reduction of triangulation, and photogrammetric surveying as may be arranged.

2143. *SEMINAR IN GEODESY OR PHOTOGRAMMETRY*. Credit 1 to 6 hrs. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the geodetic or photogrammetric field.

HYDRAULICS AND HYDRAULIC ENGINEERING

Messrs. BOGEMA, CHRISTENSEN, JORISSEN, MAYER, and MONKMEYER.

2301. *FLUID MECHANICS*. Credit 3 hrs. 3 Rec. Prereq., 1152. Fluid properties. Pressure and pressure intensity. Hydrostatics. Fluid flow concepts and basic equations. Dimensional analysis. Similitude. Laminar and turbulent flow. Flow in pipes. Flow in open channels. Flow around immersed bodies.

2302. *APPLIED HYDRAULICS AND HYDROLOGY*. Credit 3 hrs. 2 Rec. 1 Lab. Prereq., 2301. Application of fluid mechanics principles to hydraulic problems. Flow in open channels. Flow measurement. Hydraulic machinery. Elements of hydrology.

2303. *ADVANCED HYDRAULICS*. Credit 3 hrs. Fall. 3 Rec. Prereq., 2302 or 2331. More detailed and extended theory and application than the first course. Problems considered include stability of flotation, barometric leveling, fluids subject to acceleration, hydraulic similitude, water hammer, and open channel flow.

2304. *HYDRAULIC MEASUREMENTS*. Credit 3 hrs. Fall. 3 Rec. Prereq., 2302. The general flow equation. Volumetric and weight measurements. Pressure and pressure intensity. Measurements of fluid velocity. Rate of flow measurements in pipelines and open channels. Measurements under special conditions. Graphical and analytical methods of analyzing data. Errors and tolerances.

2305. *HYDRODYNAMICS*. Credit 3 hrs. Spring. 3 Lect. Prereq., 2302 or 2331 and differential equations. Equations of motion for nonviscous liquids, force potentials, velocity potentials, conformal mapping, circulation, vortices, equations of motion for viscous liquids, boundary layer, separation, drag, turbulence, and wave motion.

2306. *PUMPS AND TURBINES*. Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereq., 2302 or 2331. Theory and characteristics of the hydraulic ram; reciprocating and centrifugal pumps; impulse, reaction, and propeller type turbines; selection and testing of hydraulic machinery.

2307. *FLOW OF LIQUIDS IN OPEN CHANNELS*. Credit 3 hrs. Fall. 3 Lect. Prereq., 2302. Uniform flow, gradually varied flow, rapidly varied flow, subcritical transitions, waves, supercritical transitions, bends, precipitous slopes, energy dissipation, and spillways.

2308. *HYDRAULIC MODELS*. Credit 3 hrs. Spring. 1 Rec. 2 Lab. Prereq., 2302. Theory of similitude and its application to models. Dimensional analysis, development of prediction equations, observations and measurements, theory of models, design and construction of models, distorted models, models of rivers, spillways, and outlet works.

2331. *FLUID MECHANICS*. Credit 3 hrs. 3 Rec. Prereq., 1152. Statics, dynamics of fluid flow, law of continuity, energy equation, turbulence, flow of compressible fluids, impulse momentum relations, resistance of submerged bodies, lubrication, and hydraulic machinery.

2342. *HYDRAULICS RESEARCH*. Prereq., 2302 or equivalent. The subject and scope of the investigations in experimental or theoretical hydraulics should be selected by conference at the beginning of the term if not previously arranged. It is permissible and often desirable for two students to work together on the same investigation.

2343. *HYDRAULICS SEMINAR*. Credit 1-6 hrs. Abstraction and discussion of technical papers and publications in the hydraulics engineering field.

2403. *HYDRAULIC STRUCTURES*. Credit 3 hrs. Spring. 3 Rec. Prereq., 2412. Discussion of advanced problems related to hydraulic structures. Stress analysis in dams. Design of arch dams. Sedimentation. Spillways and river protection works. Channel transitions and controls. Hydraulics of locks.

2404. *WATER POWER*. Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 2302. Hydrologic and hydraulic investigation of water power sites; selection of turbines, power plant layout and equipment; economic considerations. Problems cover determination of available power, selection of turbines, use of pondage and storage, and determination of annual power output.

2411. *RIVERS AND HARBORS*. Credit 3 hrs. Fall. 3 Lect. Prereq., 2302 and 2412. Rivers: regimen of flow in natural streams, flood waves, flood control, sedimentation, channel improvement, canalization, tidal effects, and ports. Harbors: gravity waves, shore improvement, harbor improvement, ports, and canals.

2412. *HYDRAULIC ENGINEERING*. Credit 3 hrs. 3 Rec. Prereq., 2302. Introduction to hydraulic engineering problems. Purpose, planning, and component parts of hydraulic projects. Flood routing, sedimentation. Ground water hydraulics. Reservoirs. Dams, spillways, and river protection works. Flumes and channels. Conduits, tunnels, penstocks. Locks. Hydraulic model studies.

2442. *HYDRAULIC ENGINEERING RESEARCH*. Prereq., 2412 and one additional elective course in field of selected research. Subject and scope of investigation to be undertaken is selected by conference at beginning of term. Extraction of pertinent data from all available sources; construction and operation of hydraulic laboratory models.

2443. *HYDRAULIC ENGINEERING SEMINAR*. Credit 1-6 hrs. Discussion of selected topics in the hydraulic engineering field.

SANITARY ENGINEERING

Messrs. GATES and LYNCH.

2501. *MICROBIOLOGY IN ENGINEERING*. Credit 3 hrs. 2 Lect.-Rec. 1 Lab. Prereq., Chemistry 106. Introduction to the nature, characteristics, and activities of microorganisms and their effects on man and his environment, emphasizing their roles in the aerobic and anaerobic decomposition of organic substances, the deterioration of engineering materials, and the transmission of diseases. The application of these principles and phenomena to civil engineering.

2502. *WATER SUPPLY AND SEWERAGE SYSTEMS*. Credit 3 hrs. 2 Lect.-Rec. 1 Comp. Prereq., 2301. Introduction to the function and design of structures and appurtenances for (1) the collection, conveyance, and distribution of water for municipal use, (2) the collection and transportation of municipal wastes and storm water. Computation periods include individual reports on design problems.

2503. *WATER AND WASTE TREATMENT*. Credit 3 hrs. 2 Lect.-Rec. 1 Comp. or Lab. Prereq., 2301, 2501. Study of water and waste treatment processes in terms of the underlying physical, chemical and biological principles; the application of these principles to the function and design of unit treatment processes and of integrated treatment plants. The influence of the natural purification of streams on waste treatment and waste disposal.

2504. *SANITARY BIOLOGY AND STREAM SANITATION*. Required of graduate students who have not had 2501 or its equivalent. Credit 3 hrs. 2 Lect.-Discuss.

1 Lab. Either term. Fundamentals and methods of microbiology and their application to the bacteriology and biology of water and waste treatment processes, and to the natural purification of polluted waters. Methods for estimating and evaluating the capacities of streams to assimilate wastes.

2506. *ADVANCED WATER SUPPLY*. Credit 3 hrs. Prereq., 2503. Lectures, problems, reports, and field trips. Advanced study of water treatment processes and of water supply methods, and their application to the design of municipal and industrial water treatment plants; water quality standards and control methods.

2507. *ADVANCED WASTES TREATMENT*. Credit 3 hrs. Prereq., 2503. Lectures, problems, reports, and field trips. Advanced study of waste treatment processes; the design of treatment units and treatment plants; waste disposal and water pollution control methods. Study of current literature.

2508. *INDUSTRIAL AND NUCLEAR WASTES*. Credit 3 hrs. Prereq., 2503. Basic industrial waste treatment processes and disposal methods. Specific industrial waste problems and treatment processes. Nature, treatment, and disposal of nuclear reactor and other radioactive wastes.

2509. *PUBLIC HEALTH AND COMMUNITY SANITATION*. Credit 3 hrs. Spring. 3 Lect.-Discuss. An introduction to public health principles and practice; including the nature and activities of local, state, federal, and world public health organizations. Environmental sanitation emphasizing water supply, waste disposal, sanitation of food, air, shelter, and occupational hygiene.

2510. *SANITARY CHEMISTRY*. Credit 3 hrs. 2 Lect.-Discuss. 1 Lab. Prereq., 1 year of college chemistry. Primarily intended for graduate students and upperclassmen especially interested in sanitary engineering. Fundamentals of analytical, physical, and organic chemistry specifically applicable to the design and control of water and waste treatment processes.

2511. *SANITARY ENGINEERING LABORATORY*. Credit 3 hrs. 1 Lect.-Discuss. 2 Labs. Prereq., 2510 or parallel registration; 2503. Laboratory studies of water and waste treatment processes, including the application of physical, chemical, and biological principles, methods, and procedures to the treatment of water, sewage, and industrial wastes.

2532. *MUNICIPAL SANITATION*. For non-civil engineering students. Credit 3 hrs. Fall. Lectures, reports and field trips. Water supply and waste disposal methods, and community sanitation as they relate to municipal and regional management and planning. Operational and administrative aspects of water and waste treatment facilities, and of stream pollution control programs.

2541. *PROJECT, SANITARY ENGINEERING*. Credit 3 hrs. Prereq., 2502 and 2503 or equivalent courses. Students will elect or be assigned individual or group design problems dealing with sewerage systems, water supply, or water distribution systems; water treatment plants; municipal waste treatment and industrial waste treatment plants.

2542. *SANITARY ENGINEERING RESEARCH*. Prerequisites will depend upon the particular problem to be pursued, but in general they should include water analysis and those courses in hydraulics and sanitary engineering pertinent to the field in which the study is to be undertaken. Hours and credit variable.

2543. *SANITARY ENGINEERING SEMINAR*. Open to interested upperclassmen and graduate students. Credit 1-6 hours. Presentation and discussion of technical papers and publications in the sanitary field.

TRANSPORTATION ENGINEERING

Messrs. BELCHER, LEWIS, and LIANG.

2602. *TRANSPORTATION*. Credit 3 hrs. 3 Rec. Prereq., Economics 103 or consent of the instructor. The historical, economic, regulatory, construction, and operational aspects of transportation. Designed particularly for engineering students.

2610. *HIGHWAY ENGINEERING*. Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 2113, and preceded by or taken concurrently with 2725. Highway administration, planning, economy, and finance; location (aerial photo methods included); elements of geometric design, intersections; traffic engineering; drainage; highway materials and soils; subgrade structure; base courses; design and construction of flexible and rigid pavements.

2612. *HIGHWAY LABORATORY—BITUMINOUS*. Credit 3 hrs. Spring. 2 Labs. 1 Seminar. Prereq., 2610, or may be taken concurrently with 2610. Bituminous materials are tested and aggregates studied for their compatibility with bitumens. Mixes are designed and tested. Condition surveys are made on various classes of bituminous pavements. Laboratory fully equipped for all phases of applied and research studies.

2613. *HIGHWAY LABORATORY—STABILIZATION*. Credit 3 hrs. Fall. 2 Labs. 1 Seminar. Prereq., 2725 and 2610, or may be taken concurrently with 2610. Evaluation of current soil stabilization practices. Correlation of field and laboratory compaction procedures. Freeze-thaw and strength tests on soil samples stabilized with bituminous materials, Portland cement, and chemicals. Condition surveys are made on stabilized roads. Laboratory fully equipped for all phases of applied and research studies.

2614. *HIGHWAY DESIGN—STRUCTURAL*. Credit 3 hrs. Fall. 3 Rec. Prereq., 2610, or consent of the instructor. Part I: Soil index properties and highway soil classification systems; surveying and sampling; subgrade evaluation, including field and laboratory CBR; subgrade modulus; compaction, drainage, and frost action; stabilization; aggregates. Part II: Design and construction of base and surface courses for flexible pavements. Part III: Design and construction of rigid pavements.

2615. *HIGHWAY DESIGN—GEOMETRIC*. Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq., 2610, or consent of the instructor. Route selection; design controls and criteria, including vehicle characteristics and highway capacity; sight distance, and horizontal and vertical control; cross section elements; right-of-way problems and access control; at-grade intersection design, including rotary and channelized intersection; grade separations and interchanges; regional systems of highways, freeways, and parkways.

2617. *AIRPORT ENGINEERING*. Credit 3 hrs. Spring. 2 Rec. and 1 Lab. Prereq., 2610, 2725. Airport administration, planning, and design. Site selection—size and location; design standards; airport layout—runway patterns and orientation; flexible and rigid pavement design; drainage, gradings; marking and lighting.

2618. *LOW-COST ROADS*. Primarily for foreign students. Credit 3 hrs. Prereq., 2610 or its equivalent. Study of economic importance of routes and selection of roads (farm-to-market) to be improved; location and design; subgrade soils and stabilization of subgrade soils by use of admixtures, chemicals, and bituminous materials; drainage structures; bituminous treatments and bituminous mats for stabilized subgrades. Survey of the experimental work in the use of materials and design and construction of low-cost roads.

2619. *TRAFFIC ENGINEERING—OPERATIONS*. Credit 3 hrs. 2 Lab. 1 Seminar. Prereq., preceded by or taken concurrently with 2620. Definition of traffic problems;

collection of field data; analysis of field data; findings, conclusions, and recommendations. Traffic surveys. Design of traffic control systems.

2620. *TRAFFIC ENGINEERING*. Credit 3 hrs. 2 Rec. 1 Lab. Prereq., 2610, or consent of the instructor. City and highway traffic surveys and designs. Accidents, congestion, delay, speed, volume, density, parking, channelization, lighting, traffic control and routing. Signs, signals, and markings. Urban traffic consideration in city planning. Driver reactions and habit pattern. Traffic engineering organization.

2621. *ANALYSIS AND INTERPRETATION OF AERIAL PHOTOGRAPHS*. Preregistration required. Credit 3 hrs. 2 Lect. 1 Lab. (The student is expected to pay the cost of field trips and aerial photographs for use in a term project which amounts to approximately \$15.) A study of the soil and rock areas of the United States and the patterns present in aerial photographs. Fundamental elements of soil patterns are analyzed to permit determination of soil texture, type of bedrock, and drainage properties. Field training in selected test areas. Emphasis is placed on interpretation for engineering, regional planning, and agricultural purposes.

2622. *ADVANCED INTERPRETATION OF AERIAL PHOTOGRAPHS*. Preregistration required. Credit 3 hrs. Organization of course depends upon fields of interest. Special problems: four each on ground water, engineering projects, agricultural soils mapping, irrigation, and geology.

2641. *PROJECT, TRANSPORTATION ENGINEERING*. Credit 3 hrs. Projects in the various fields of transportation, advanced aerial photographic studies, and traffic engineering may be developed by conference between professors and students. Projects may involve integrated planning or design drawing upon several fields of interest, or they may concentrate upon special subjects. Adequate facilities, material, and sources of data are necessary to a satisfactory project.

2642. *TRANSPORTATION ENGINEERING RESEARCH*. Students who wish to pursue one particular branch of transportation engineering further than can be done in any of the regular courses may elect work in this field. The work may be in the nature of an investigation of existing methods or systems, theoretical work with a view to simplifying present methods of design or proposing new methods, or experimental investigation of suitable problems.

2643. *TRANSPORTATION ENGINEERING SEMINAR*. Credit 1-6 hrs. Number of meetings a week to be arranged. Abstraction and discussion of selected technical papers and publications in the transportation engineering field.

STRUCTURAL ENGINEERING

Messrs. BIJLAARD, FISHER, HOUGH, MASON, McGUIRE, NILSON, SUJATA, and WINTER.

2701. *ELEMENTARY STRUCTURAL ANALYSIS*. Credit 3 hrs. 2 Rec. 1 Lab. Prereq., 1153. A first course in structural theory. Determination of reactions and internal forces and moments in beams, girders, trusses, simple frames, and three-hinged arches due to stationary and moving loads. Use is made of graphical and analytical methods and of influence lines.

2702. *STEEL AND TIMBER STRUCTURES*. Credit 3 hrs. 3 Lab. Prereq., 2701. Analysis and design of steel members and connections. Design of welded and riveted roof trusses. Design of steel railway girder bridge. Characteristics, properties, and mechanics of timber. Partial design of segmental-member timber-roof truss.

2704. *STATICALLY INDETERMINATE STRUCTURES*. Credit 3 hrs. 3 Lect. Prereq., 2702. Deflections. Classical and modern methods of analysis of statically

indeterminate beams, frames, trusses. Influence lines. Members of varying cross section.

2706. *ADVANCED STEEL DESIGN*. Credit 3 hrs. 3 Lab. Prereq., 2713 or the equivalent. Critical study of current specifications for the design of steel buildings. Steel framing systems in current use. Problems in the analysis and design of commercial and industrial buildings, and of special structures.

2709. *ADVANCED STRUCTURAL ANALYSIS*. Credit 3 hrs. 3 Rec. Prereq., 2704 or equivalent. Review of fundamental methods for solving indeterminate structures and extension to more involved problems. Curved beams, arches, rings, space frames. Numerical methods, limit analysis, model analysis.

2710. *STRENGTH OF STRUCTURES*. Credit 3 hrs. 3 Rec. Prereq., 2704; can be taken concurrently. Analysis of two- and three-dimensional stress and strain. Theories of failure of ductile and brittle materials. Strain energy methods applied to bending, shear, buckling, and impact. Structural materials under load, strain hardening, residual stresses, hysteresis, stress concentration, alternating stress. Design for fatigue. Stresses beyond the elastic limit. Plastic or ultimate design of steel and reinforced concrete structures. Critical discussion of current design specifications.

2711. *BUCKLING OF STRUCTURES*. Credit 3 hrs. 3 Rec. Prereq., 2710 and 1145 or equivalent. Analysis of elastic and plastic stability. Determination of buckling loads and maximum stresses of columns with and without initial crookedness and eccentricity. Solid and open web columns with variable cross-section. Beam columns. Lateral strength of unbraced beams. Buckling loads and ultimate strength of thin plates. Critical discussion of current design specification.

2713. *STRUCTURAL DESIGN*. Credit 3 hrs. 3 Lab. Prereq., 2702, 2704, 2715, 2720. Primarily a project course. Discussion of fatigue, limit design, light gage steel design. Design of a highway truss bridge. Planning and design of representative portions of a complete structural project (building, bridge, or other structure selected by student). Integrated use of procedures presented in other courses.

2715. *REINFORCED CONCRETE DESIGN*. Credit 3 hrs. 3 Lab. Prereq., 2704; can be taken concurrently. A first course in reinforced concrete. Elementary theory of reinforced concrete applied to rectangular slabs, T-beams, beams reinforced for compression, columns, and footings. Shear and direct stress combined with flexure. Bond. Elastic and ultimate theory. Several design reports which include reinforcement drawings, schedules, and formwork.

2716. *ADVANCED REINFORCED CONCRETE DESIGN*. Credit 3 hrs. 3 Lab. Prereq., 2715 or equivalent. Study of background of current specifications for the design of concrete structures. Study of concrete building framing systems in current use. Yield line theory. Representative design problems, e.g., flat slab building, highway bridge, arch.

2717. *BRIDGE DESIGN*. Credit 3 hrs. Prereq., 2704, 2715. Design of more complex types of steel and concrete bridges, such as continuous truss, multiple box culvert, rigid frame, arch. Basic planning of bridge project and study of problems common to all types of bridges, including substructures. Attention is given to traffic, hydraulic, and economic requirements, and use of field data, preliminary surveys, and model studies.

2718. *PRESTRESSED CONCRETE*. Credit 2 hrs. Properties of material used in prestressed concrete. Creep of concrete. Prestressing methods. Design of statically determinate prestressed members. Ultimate strength and factors of safety. Discussion of statically indeterminate systems. Application of prestressing to complete structures.

2719. *ENGINEERING PLASTICITY*. Credit 2 hrs. 2 Rec. Prereq., 2710 and 1145

or equivalent. Plastic behavior as based on crystalline structure. Brittle vs. plastic behavior. Mechanism of plastic deformation and plasticity condition. Flow lines. Application to strength of metal structures and geophysics. Plastic buckling of columns and plates.

2720. *FOUNDATIONS*. Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 2715, 2725. Study of the structural problems encountered in foundation work. Retaining walls, sheet piling, spread footings, piles, piers, abutments, cofferdams, caissons, underpinnings. Design problems. Introduction to geophysical exploration.

2725. *ELEMENTS OF SOILS ENGINEERING*. Credit 3 hrs. 2 Lect. 1 Lab. Prereq., Geology 113, Eng. 1153, 2301. Formation and composition of soil, its properties, and its behavior as an engineering material. Principles of soil identification and classification, terminology and soil characteristics such as gradation, permeability, compressibility, consolidation, and shearing strength with application to simple problems of seepage, settlement, bearing capacity, stability of earth slopes. Lateral earth pressure. Soil exploration. Laboratory tests for experimental determination of above mentioned soil characteristics and evaluations and use of data.

2726. *SOILS ENGINEERING THEORY*. Credit 3 hrs. Fall. 3 Lect. Prereq., 2725. Principles of mechanics and strength of materials relating to typical soils engineering problems and the fundamental physical and chemical characteristics of soil which affect their application. Methods for determining the distribution of stresses in semi-infinite soil masses, stress at a point, and the Mohr theory of rupture. Composition, structure, and stress-strain characteristics of soil. Calculation of settlement of structures, the stability of earth slopes and of embankment foundations. Basic principles of flow of water through soil, flow net construction, rate and effect of seepage. Lateral earth pressure theory.

2727. *APPLIED SOILS ENGINEERING*. Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 2726. Application of soils engineering theory of problems. Planning and conducting of subsurface investigations, determination of significant physical and chemical soil characteristics by test or other means, including appropriate laboratory exercises, analysis of actual designs of proposed structures for prediction of settlement, stability, rate of seepage, or other service requirements, methods of inspection and control of earthworks construction, selection and placement of materials, compaction and stabilization.

2731. *ELEMENTS OF STRUCTURAL ENGINEERING I*. Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 1151, 1153. Analysis of statically determinate and simple statically indeterminate structures. Determination of reactions and internal forces and moments caused by stationary loads, by means of analytical and graphical methods.

2732. *ELEMENTS OF STRUCTURAL ENGINEERING II*. Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 2731. Design of simple steel and timber structures. Analysis and design of members and connections, roof trusses, floor systems, and other structures.

2741. *PROJECT*. Prereq., 2702, 2703 and 2715. The student may select a design problem such as the following: (a) an arch bridge, (b) a cantilever bridge, (c) a rigid frame bridge, (d) a special problem in steel or concrete building design, (e) the design of any other structure of particular interest to the student provided he has had the proper preparation for such design. The work is submitted in the form of reports. Drawings of typical details must accompany reports.

2742. *STRUCTURAL ENGINEERING RESEARCH*. Students wishing to pursue one particular branch of structural engineering further than can be done in any of the regular courses may elect work in this field. The prerequisite courses depend upon the nature of the work desired. The work may be in the nature of an investigation of existing types of construction, theoretical work with a view of simplifying

present methods of design or proposing new methods, or experimental investigation of suitable problems.

2743. *STRUCTURAL ENGINEERING SEMINAR*. Credit 1-6 hrs. Open to specially selected seniors or graduate students. Preparation and presentation of topics of current interest in the field of structures for informal discussion.

2744. *SPECIAL TOPICS IN STRUCTURAL ENGINEERING*. Individually supervised study in one or more of the specialized topics of civil engineering such as tanks and bins, suspension bridges, towers or movable bridges, which are not covered in the regular courses. Independent design or research projects may also be selected.

SPECIAL AND GRADUATE COURSES

2801. *THESIS*. The thesis gives the student an opportunity to work out a special problem or to make an engineering investigation, to record the results of his work, and to obtain academic credit for such work. Registration for thesis must be approved by the professor in charge at the beginning of the semester during which the work is to be done.

NOTE: Individual courses may be arranged to suit the requirements of graduate students. They are intended to be pursued under the immediate direction of the professor in charge, the student usually being free from the restriction of the classroom and working either independently or in conjunction with others taking the same course.

ADMINISTRATIVE ENGINEERING

Messrs. CRANDALL, GEBHARD, and ROGERS.

2901. *CONSTRUCTION METHODS*. Credit 3 hrs. 3 Rec. Introduction to methods, equipment, and management principles and procedures involved in construction enterprises; nature of the construction industry and sources of information concerning it; problems and oral reports by students based on current literature; correlation of money, men, materials, machines, and design details to produce economic results.

2902. *ENGINEERING LAW*. Credit 3 hrs. 3 Rec. Basic features of laws of contract, tort, agency, real property, water rights, forms of business organizations, sales, negotiable instruments, workmen's compensation, mechanics' liens, bankruptcy, wills, patents, copyrights, trademarks; work of the expert witness; special emphasis on contract documents used in construction work.

2903. *ECONOMICS OF ENGINEERING*. Credit 3 hrs. 3 Rec. Prereq., 2901, 3231. Principles governing the economic aspects of engineering decisions; time-value of money; economic selection of materials, equipment, and structures; retirement and replacement studies; economic studies for public works. Techniques in estimating costs of engineering construction projects.

2904. *PUBLIC ADMINISTRATION*. Credit 3 hrs. 3 Rec. Administrative aspects of federal, state, and local governments of particular interest to engineer-administrators; government functions which affect the engineer; procedures and practices; general problems of the city; city planning and zoning; revenues and expenditures; budgets; controlling legislation; civil service; and related topics.

2905. *VALUATION ENGINEERING*. Credit 3 hrs. 3 Rec. Prereq., 2901, 2902, 2903, 3231. Theory and practice of estimating the present worth of specific properties for utility rate making; buying and selling, eminent domain and condemnation

proceedings, securities; bank loans, mortgages, insurance, uniform systems of accounting, and improving management.

2906. *ADVANCED ENGINEERING LAW*. Credit 3 hrs. 3 Rec. Prereq., 2902. An extension by the use of case material of some of the legal principles covered in 2902, particularly those which apply to construction contracts, and employer-employee relationships; also additional coverage in suretyships, insurance, bailments, and conditional sales.

2907. *CONSTRUCTION MANAGEMENT*. Credit 3 hrs. Prereq., 2901, 2902, 2903, 3231. Top level planning and operation of construction projects by the civil engineer; coordinated organization and control of men, materials, and machines; scheduling, estimating, purchasing, selection, and training of employees; operation and maintenance of equipment; cost control and pay systems; accident prevention; and other topics. Special reports required.

2941. *PROJECT. ADMINISTRATIVE ENGINEERING*. Credit 3 hrs. Prereq., 2901, 2902, 2903. Development of a public or private engineering project selected by the student involving economic analysis, planning, design, and construction procedures, with special emphasis on the legal, financial, and management aspects.

2942. *ADMINISTRATIVE ENGINEERING RESEARCH*. Credit 3 hrs. Prereq., 2901, 2902, 2903. Investigation of special problems relating to the economic, legal, financial, and management aspects of public and private engineering operations of interest to the engineer-administrator, consulting engineer and constructor.

2943. *ADMINISTRATIVE ENGINEERING SEMINAR*. Credit 1-6 hrs. Prereq., 2901, 2902, 2903. Guided study and discussions by small groups of selected students of topics which involve the legal, financial, and management aspects of civil engineering in public and private work, including discussions of current technical papers and publications.

MECHANICAL ENGINEERING

The courses in mechanical engineering are listed under the following headings: Drafting and Industrial Design, Thermal Engineering, Industrial and Engineering Administration, Machine Design, Materials Processing.

Required courses in the mechanical engineering curriculum given outside the College of Engineering are as follows (pages 129-137):

Chemistry 105, 106. General Chemistry
Chemistry 301. Introduction to Organic Chemistry
Chemistry 402. Introduction to Physical Chemistry
English 111, 112. Introductory Course
Mathematics 161, 162, 163. Analytic Geometry and Calculus
Physics 115. Mechanics
Physics 116. Wave Motion, Sound, and Heat
Physics 117. Electricity and Magnetism
Physics 118. Physical Electronics and Optics
Public Speaking 101.

Required courses in mechanics of engineering, strength of materials, and engineering materials are described on pp. 93-96.

GENERAL

3001. *INTRODUCTORY ENGINEERING*. Credit 1 hr. 2 Lect. An orientation to the School and to the field of mechanical engineering. A study of the slide rule, problems in engineering, plotting of data, and report writing.

3002. *INTRODUCTORY ENGINEERING*. Credit 2 hrs. 2 Lect. A continuation of Course 3001 with special emphasis on the responsibilities and opportunities that exist for mechanical engineers in industry. An introduction to modern industrial organization.

3041. *NONRESIDENT LECTURES*. Terms 9 and 10. Required. Total credit 1 hr. for both terms. Fall and spring. 1 Lect.

The course consists of a series of lectures given by lecturers invited from industry and from certain other departments of the University for the purpose of assisting students in their approach to employment and in their transition from college to industrial life.

3051. *A.S.M.E. STUDENT BRANCH*. Credit 1 hr. Students who have completed at least two terms in the School of Mechanical Engineering are urged to become members of the Cornell Student Branch of the American Society of Mechanical Engineers. The meetings of the Society, however, are open to all. Attendance at any fourteen Student Branch meetings entitles the member to one hour elective credit; however, only one elective hour may be earned in this manner. Application for membership should be made in October of each year at the A.S.M.E. office, or to the Honorary Chairman of the Student Branch.

DRAFTING AND INDUSTRIAL DESIGN

Messrs. ABRAHAM, BAIRD, CLEARY, and SIEGFRIED.

3111. *DESCRIPTIVE GEOMETRY AND FREEHAND DRAWING*. Credit 3 hrs. Fall. 1 Lect. 2 Lab. Introduction to prerequisite arts and sciences of mechanical drafting and creative sketching; lettering; delineation; isometric; descriptive geometric anatomy; freehand pictorial and orthometric drawing; esthetics; introductory creative sketching.

3112. *BASIC MECHANICAL DRAFTING AND CREATIVE SKETCHING*. Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq., 3111. Basic mechanical drafting principles and standards; creation, expression and interpretation of specifications for the properties of mechanical anatomy by layouts and working drawings; continuation of creative sketching.

3114. *FREEHAND DRAWING*. Credit 1 hr. Fall. 1 Lect. For students who desire only the freehand content of 3111.

3115. *CREATIVE SKETCHING*. Credit 1 hr. Spring. 1 Lect. Prereq., 3111 or 3114. For students who desire only the creative sketching content of 3112.

3116. *INTRODUCTION TO INDUSTRIAL DESIGN*. Credit 3 hrs. Spring. 2 Lab. Prereq., 3111 and 3112. Demonstration of interrelationships of form, function, and materials by special exercises in designing practical structures for appearance and use. Presentations by a variety of media using perspective, other types of graphic representations, and models.

3117. *DESCRIPTIVE GEOMETRY*. Credit 2 hrs. Fall. 2 Lab. Same as 3111 except that freehand content is omitted.

3118. *BASIC MECHANICAL DRAFTING*. Credit 2 hrs. Spring. 2 Lab. Same as 3112 except that creative sketching content is omitted.

3131. *SPECIAL PROBLEMS IN DRAFTING OR INDUSTRIAL DESIGN*. Credit based upon actual hours of work. Fall or spring. Lab. as required. Also may be elected by students who desire the first term only of the Industrial Design Project.

3198, 3199. *INDUSTRIAL DESIGN PROJECT*. Total credit 6 hrs. Ninth and

tenth terms. 2 Lab. Prereq., 3116. Projects which integrate training in mechanical engineering when such work is done principally in the field of industrial design.

INDUSTRIAL AND ENGINEERING ADMINISTRATION

Messrs. ALLEN, BECHHOFFER, CONWAY, GAVETT, HANSELMAN, KAO, KRICK, LOBERG, McGARRAH, SAMPSON, SAUNDERS, SCHULTZ, and WEISS.

3231. *PRINCIPLES OF INDUSTRIAL ACCOUNTING AND COST FINDING*. Credit 3 hrs. Fall and spring. 2 Lect. 1 Comp. Basic course in principles of industrial accounting including controlling accounts; special journals and ledgers; voucher system; manufacturing cost systems.

3232. *PERSONNEL MANAGEMENT*. Credit 3 hrs. Fall. 3 Rec. Intended for graduate students but open to qualified undergraduates. Prereq., 3241 or permission. Techniques of employee selection and evaluation, job evaluation, training, motivation; personnel department organization and interdepartmental relations.

3233. *REPORT WRITING*. Credit 1 hr. Offered on demand. 1 Rec. Engineering students only. Organization of engineering material into concise written form; preparation of engineering reports including organization, description of apparatus and procedures, graphical presentation and summary of results; business letters; written specifications.

3235. *INDUSTRIAL ORGANIZATION AND MANAGEMENT*. Credit 3 hrs. Fall. 3 Lect. Management of an industrial enterprise; internal organization; effect of type of product, methods of manufacture, size of enterprise, and personnel involved; types of enterprises; plant location; centralization and decentralization trends; diversification and specialization; growth of industry.

3236. *ORGANIZATION AND MANAGEMENT OF PRODUCTION*. Credit 3 hrs. Spring. 2 Lect. 1 Rec. Introductory course in industrial management covering organizational structure; principles of mass production; plant location and layout; methods analysis and time study; production planning and control; related functions of engineering, research, sales, purchasing, and cost control; technology, technical organization, and background of scientific management.

3240. *ANALYTICAL METHODS IN OPERATIONS RESEARCH*. Credit 3 hrs. 3 Rec. Intended for graduate students but open to qualified undergraduates. Selected topics of special interest in operations research and industrial engineering including matrix algebra, set theory, convex bodies, linear inequalities, probability theory (including Markoff chains) and applications to selected problems.

3241. *INDUSTRIAL AND ENGINEERING STATISTICS*. Credit 3 hrs. Fall and spring. 2 Rec. 1 Comp. Prereq., Calculus. Applications of probability theory and statistics to industrial and engineering problems; point and confidence interval estimation; statistical testing of hypotheses; properties of binomial, Poisson, and hypergeometric distributions, and applications to sampling inspection problems; large-sample theory and the normal distribution, small-sample theory and student's T and the Chi-square distributions; introduction to correlation theory and curve fitting by least squares.

3242. *STATISTICAL CONTROL AND SAMPLING INSPECTION*. Credit 3 hrs. Spring. 2 Rec. 1 Comp. Elective for qualified undergraduate and graduate students. Prereq., 3241 or permission. Underlying theory, assumptions, applications, and limitations of control charts and sampling plans; concept of statistical control, Shewhart control charts, and sampling inspection for attributes and variables; organi-

zation, administration, and economic problems, and application of concepts to areas other than quality maintenance.

3243. INTERMEDIATE INDUSTRIAL AND ENGINEERING STATISTICS. Credit 3 hrs. Spring. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereq., 3241 or permission. Application of statistical methods to the efficient design, analysis, and interpretation of industrial and engineering experiments; rational choice of sample size for various statistical tests and the operating characteristic curves of these tests; curve fitting by least squares; introduction to the analysis of variance.

3244. ADVANCED INDUSTRIAL AND ENGINEERING STATISTICS. Credit 3 hrs. Fall. 2 Rec. 1 Comp. Intended for graduate students. Prereq., 3243 or permission. Use and analysis of experimental designs such as randomized blocks and Latin squares; analysis of variance and covariance; factorial experiments; statistical problems associated with finding best operating conditions; statistical multiple-decision selection procedures.

3246. PRINCIPLES OF INDUSTRIAL ACCOUNTING. Credit 2 hrs. Fall. 1 Lect. 1 Comp. Basic accounting theory; special journals; controlling accounts and subsidiary records; voucher system; basic manufacturing cost accounting.

3247. PRINCIPLES OF COST CONTROL. Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereq., 3246, 3231, or equivalent. Principles of cost accounting for production order and continuous process operations; cost factors related to decision making, control and profit; budgets and standards; cost analyses.

3253. CHEMICAL ENGINEERING COST ACCOUNTING. Credit 3 hrs. Fall and spring. 2 Lect. 1 Comp. Basic accounting theory; manufacturing cost accounting and cost analysis in the chemical industry; standards, budgetary control, profit analysis and statement analysis discussed briefly.

3254. OPERATIONS PLANNING AND CONTROL. Credit 3 hrs. Fall. 2 Rec. 1 Comp. Elective for graduate students and qualified undergraduates. Prereq., 3247 or 3253. Profit analysis, budgetary planning, forecasting, cost control, and cost analysis applied to production and sales; decision problems and quantitative methods of approaching complex planning, programming, and assignment problems.

3261. MANUFACTURING ENGINEERING. Credit 3 hrs. Spring. 2 Rec. 1 Lab. Elective for graduate students. Prereq., 3247 or 3253, 3262, 3404 or equivalent. Economics applied to capital investment decisions; analytical techniques for process design, plant layout, materials handling, production management.

3262. METHODS ENGINEERING. Credit 3 hrs. Fall and spring. 1 Lect. 2 Lab. Prereq., 3241 or equivalent. Analysis and design of operations and jobs; factors influencing creation and evaluation of alternative designs; work measurement and other techniques including stop-watch time study, work sampling, queueing, and predetermined motion times as used for evaluation of design, control of operations, wage standards, etc.

3263. PRODUCTION ENGINEERING. Credit 3 hrs. Fall. 2 Rec. 1 Comp. Prereq., 3247 or 3253, 3262, 3404, or permission. The analysis of product designs for economic manufacturing consistent with functional requirements. The analysis and specification of alternative processes and assembly methods. Special emphasis is given to problems of estimating and evaluating alternative designs, processes, and procedures including the several degrees and concepts of automation.

3264. PRODUCTION ENGINEERING. Credit 3 hrs. Spring. 1 Lect. 2 Comp. Prereq., 3263. The analysis and design of integrated manufacturing systems; prin-

ciples of materials handling, plant layout, production scheduling, and inventory control. Emphasis on the interdependency of engineering and control functions.

3265. *PRODUCTION CONTROL*. Credit 3 hrs. Spring. 2 Rec. 1 Comp. Intended for graduate students but open to qualified fifth year students. Prereq., 3241, 3261 or 3264. Programming manufacturing operations; production forecasting, scheduling, dispatching, follow-up; inventory control; linear programming and statistical methods as techniques to establish decision rules for these functions; design of systems and procedures.

3266. *ADVANCED METHODS ENGINEERING*. Credit 3 hrs. Fall. 2 Rec. 1 Lab. Intended for graduate students but open to qualified undergraduates. Prereq., 3262 or permission. Analysis of methods engineering techniques and means of appraising specific installations; advanced treatment of work sampling, macroscopic and microscopic standard data, maintenance of time standards, and other techniques.

3267. *ADVANCED PRODUCTION ENGINEERING*. Credit 2 hrs. Fall. 1 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereq., 3261 or 3264 or permission. A continuation of 3264 with emphasis on analytical methods of solving production design problems. Case studies will be used covering problems in receiving, processing, in-process handling and layout, storage and distribution systems.

3270. *INDUSTRIAL MARKETING*. Credit 3 hrs. Spring. 3 Lect. Elective for qualified undergraduate and graduate students. Prereq., 3241, 3247, or 3253. Industrial marketing as related to product planning, policy, and research, sales and market analysis; distribution channels; pricing and terms of sale; sales promotion; management and organization of sales force; sales control. Aspects of related purchasing problems; methods of forecasting sales.

3271. *INDUSTRIAL MARKETING RESEARCH*. Credit 3 hrs. Fall. Intended for graduate students but open to qualified undergraduates. Prereq., 3270. Techniques of market research applied to specific problems related to industrial goods.

3280. *INTRODUCTION TO OPERATIONS RESEARCH*. Credit 3 hrs. Fall. 2 Rec. 1 Comp. Intended for graduate students and qualified fifth year students. Prereq., 3241 or permission. Methodology and techniques of operations research including waiting line models, linear programming and assignment, simulation, and other specialized techniques; applications to production, cost, inventory, and sales problems.

3281. *COMPUTING EQUIPMENT AND INDUSTRIAL APPLICATIONS*. Credit 3 hrs. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereq., 3247, 3262 or permission. Principles and characteristics of modern high-speed digital and analog computing equipment. Programming and operation of the digital computer at the Cornell Computing Center. Engineering and scientific computing applications, introduction to numerical analysis, simulation and Monte Carlo techniques. Data processing applications in accounting, communications and control; problems of integrated systems design.

3284. *LINEAR PROGRAMMING AND DECISION THEORY*. Credit 3 hrs. 2 Rec. 1 Comp. Spring of even years. Intended for graduate students. Prereq., 3240 and 3243, or equivalent. Linear programming applied to problems of allocation, assignment and distribution. Statistical decision theory, relation to game theory, structure of games, strategies; the emphasis of this course will be on the basic concepts and applications, rather than on the mathematics.

3290. *SPECIAL INVESTIGATIONS IN INDUSTRIAL AND ENGINEERING ADMINISTRATION*. Credit and sessions as arranged. Fall and spring. Elective for qualified undergraduate and graduate students. Offered to qualified students indi-

vidually or in small groups. Study, under direction, of special problems in the field of industrial and engineering administration.

3291. *INDUSTRIAL AND ENGINEERING ADMINISTRATION GRADUATE SEMINAR*. Credit 1 hr. A weekly 1½ hr. meeting. Intended for graduate students. Discussion and study of assigned topics of importance in the field.

3298, 3299. *PROJECT*. Max. credit 6 hrs. Prereq., 3264. Project work requires the identification and analysis of both professional and research problems in industrial engineering. The projects emphasize analytic ability and the synthesis of feasible solutions. Projects can be done individually or in groups up to eight. The problem definition and the subsequent analysis and synthesis is the concern of the student with minimal faculty guidance and participation.

MACHINE DESIGN

MESSRS. BURR, DuBOIS, MABIE, OCVIRK, PHELAN, RAVEN, and WEHE.

3341. *MACHINE DESIGN*. Credit 4 hrs. Spring. 3 Rec. 1 Comp. Prereq., 1153, 1241, 3118, 3402, and 6110, or equivalent. Required of students in electrical engineering and agricultural engineering and may be elected by other qualified students not in mechanical engineering. The design of machines and machine members based upon considerations of motion, size, material, strength, durability, and manufacturing processes; selection of cams, linkages, couplings, clutches, brakes, bolts, chains, gears, bearings, shafts, springs, and fasteners.

3351. *MECHANISM*. Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereq., 3112, 1151. A study of displacements, linkages, cams, gears, trains of mechanism, computing linkages, and introduction to synthesis.

3352. *DYNAMICS OF MACHINERY*. Credit 3 hrs. Spring. 3 Rec. Prereq., 3351 and 1152. Graphical and analytical studies of velocities and accelerations and of static and inertia forces in mechanism; engine force analysis, flywheels, and balancing; gyroscopic loads; shaft whirl; vibration isolation.

3353. *DESIGN OF MACHINE MEMBERS*. Credit 3 hrs. Fall. 2 Rec. 1 Comp. Prereq., 3351, 1153, 1242. Application of mechanics, kinematics, materials, and processes to the design and selection of springs, couplings, clutches, brakes, belts, chains, gears, shafts, bearings, fastenings, and pressure vessels; stress concentration, residual stresses, theory of lubrication.

3354. *DESIGN OF MACHINES*. Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq., 3353, 3404, 6112 (Prereq. or parallel). The design of complete machines and modification of existing machines; computations and layout drawings as required; the design of castings, forgings, stampings, weldments, housings, and hydraulic systems for machines.

3361. *ADVANCED MACHINE ANALYSIS*. Credit 3 hrs. Fall. 3 Rec. Intended for graduate students but open to qualified fifth year students. Prereq., 3353, 1155 (prereq. or parallel). Advanced analyses of mechanisms and machinery members such as clutches and brakes; the graphical determination of shaft deflection; problems in impact, creep, thermal stress, residual stress, surface stress, pressure vessels, and rotating disks; an extended treatment of bearing lubrication.

3362. *MECHANICAL DESIGN OF TURBOMACHINERY*. Credit 3 hrs. Offered on demand. 3 Rec. Intended for graduate students but open to qualified fifth year students. Prereq., 1154 or 3361, 1162 or 3367 (prereq. or parallel). Mechanical design of major components of high speed compressors and turbines for structural adequacy and vibration-free operation. Design of rotor components: disks, vanes, blades, shafts, and connections. Design of casing components: cylindrical, conical, torical shells;

flat plates and diaphragms. Design of bearings, seals, gaskets, expansion members. Investigation of natural frequencies and critical speeds. Selection of materials.

3366. *ADVANCED KINEMATICS*. Credit 3 hrs. Spring of even years. 2 Rec. 1 Lab. Prereq., 3352. Advanced analytical and graphical treatment of velocities and accelerations. Further treatment of Coriolis' acceleration. Advanced analysis and design of cams, gears, and computing mechanisms. Synthesis of mechanism.

3367. *DESIGN PROBLEMS IN VIBRATIONS AND DYNAMICS*. Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 1155, 3352. Applications of dynamics and vibration theory to the design of machinery; vibration and shock mounting of machines with single and multi-degrees of freedom, properties of isolators, damping devices, critical speeds of shafts and crankshaft systems; vibration instruments and experimental investigations.

3370. *SPECIAL INVESTIGATIONS IN MACHINE DESIGN*. Credit arranged. Either term. Individual work or work in small groups under guidance in the design and development of a complete machine, in the analysis of experimental investigation of a machine or component of a machine, or studies in a special field of machine design.

3372. *EXPERIMENTAL METHODS IN MACHINE DESIGN*. Credit 3 hrs. Fall. 1 Rec. 2 Lab. Prereq., 3353. Investigation and evaluation of methods used to obtain design and performance data. Techniques of photoelasticity, strain measurement, photography, vibration and sound measurements, balancing methods, and development techniques are studied as applied to machine design problems.

3374. *CREATIVE DESIGN*. Credit 3 hrs. Fall. 2 Lab. Prereq., 3354. Use of short ingenuity problems to stimulate originality, and emphasizing methods for the development of improved designs.

3375. *AUTOMATIC MACHINERY*. Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereq., 3351. A study of automatic and semiautomatic machinery such as dairy, canning, wire-forming, textile, machine-tool, computing, and printing equipment.

3376. *DESIGN OF OIL HYDRAULIC MACHINERY*. Credit 3 hrs. Spring of odd years. 2 Rec. 1 Lab. Prereq., 3353, and either 2331 or 3604. Methods of generation, application, and control of oil hydraulic power, commercial forms of fixed and variable delivery pumps, fluid motors, valves, control circuits, multispeed and sequence systems, pilot, servo, and tracer mechanisms for use in machine tools and similar applications.

3377. *AUTOMOTIVE ENGINEERING*. Credit 3 hrs. Fall of odd years. 3 Rec. Prereq., 3353. Analysis of various designs for the parts of an automotive vehicle, other than the engine, relative to its performance; stability, weight distribution, traction, steering, driving, braking, riding comfort, power required and available, transmission types, acceleration, and climbing ability. Recommended together with Course 3670 for a study of automotive engineering.

3398, 3399. *PROJECT*. Total credit 6 hrs. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of machine design. Hours of credit given for each course will depend upon the amount and quality of the work done each term.

THERMAL ENGINEERING

Messrs, ANDRAE, CONTA, McMANUS, DAVIS, DROPKIN, ERDMAN, FAIRCHILD, GEBHART, MACKEY, POWELL, SHEPHERD, and WATSON.

3601. *ENGINEERING THERMODYNAMICS*. Credit 3 hrs. Fall. 1 Lec. 2 Rec.

Prereq., Mathematics 163, Physics 116, Chemistry 106. Laws of thermodynamics; energy equations; properties of state of ideal and real fluids; processes; basic cycles of heat engines and heat pumps; properties of mixtures.

3602. *ENGINEERING THERMODYNAMICS*. Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereq., 3601, Chemistry 402. Properties of a pure substance; Maxwell relations, thermodynamics of combustion; availability, irreversibility, and equilibrium; thermodynamic analysis of complex cycles.

3603. *FLUIDS ENGINEERING I*. Credit 3 hrs. Spring. 3 Rec. Prereq., 3601, 1152. Properties of fluids; hydrostatic relations; kinematics and dynamics of fluids; incompressible and compressible flow in ducts; stagnation properties; laminar flow, turbulent flow, boundary layer, velocity distribution; compressible flow with varying area, friction and heat transfer; normal shock.

3604. *FLUIDS ENGINEERING II*. Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 3603. Dimensional analysis; flow metering; flow over immersed bodies; boundary layer; drag in incompressible and compressible flow; oblique shocks; vortex flow; energy transfer between a fluid and a rotor; characteristics of turbomachines; reaction and efficiency; pressure distribution and lift; propulsion systems; hydrodynamic couplings.

3605. *HEAT TRANSFER*. Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereq., 3603, 1155. Introduction to heat transfer by conduction, convection, and radiation; steady state, transient state; steady periodic state; heat transfer in engineering apparatus; numerical methods; electrical and fluid analogues. Laboratory instruction in temperature measurement, determination of surface coefficients, radiant energy exchange, and experimental use of analogues.

3606. *THERMAL ENGINEERING LABORATORY*. Credit 3 hrs. Spring. 1 Lect. 1 Lab. Prereq., 3602, 3604, 3605. Methods of testing; experimental determination of performance characteristics of engines, turbines, steam generating units, pumps, compressors, fans, refrigerating systems, air conditioning apparatus, auxiliaries and components of complete plants; analysis of experimental data; preparation of engineering reports.

3607. *COMBUSTION ENGINES*. Credit 3 hrs. Fall and spring. 3 Rec. Prereq., accompanied or preceded by 3606. Introduction to combustion engines with emphasis on application of thermodynamics, fluid dynamics, and heat transfer; reciprocating combustion engines; gas turbines; compound engines; reaction engines.

3608. *THERMAL POWER PLANTS*. Credit 3 hrs. Fall and spring. 3 Rec. Prereq., accompanied or preceded by 3606. Introduction to steam and binary vapor power plants with emphasis on applications of thermodynamics, fluid dynamics, and heat transfer; nuclear power.

3609. *REFRIGERATION AND AIR CONDITIONING*. Credit 3 hrs. Fall and spring. 3 Rec. Prereq., accompanied or preceded by 3606. Introduction to refrigeration and air conditioning with emphasis on applications of thermodynamics, fluid dynamics, and heat transfer; compression, absorption, and other systems of refrigeration; control of the physical environment.

3630. *ENGINEERING THERMODYNAMICS*. Credit 3 hrs. 3 Rec. Required of students in the Schools of Electrical Engineering and Civil Engineering. Prereq., Mathematics 163, Physics 116, Chemistry 106. Laws of thermodynamics; energy equations; thermodynamic properties of state of gases, vapors, and mixtures; nonflow and flow processes; gas and vapor cycles.

3642. *HEAT-POWER II*. Credit 2 hrs. Spring. 2 Lect. Required of students in the School of Civil Engineering. Prereq., 3630. Properties and processes of vapors; steam

engines; steam turbines; the elementary steam power plant; heat transfer; refrigeration and air conditioning.

3650. *SPECIAL TOPICS IN THERMAL ENGINEERING*. Spring. Credit to depend upon hours of actual work. Informal instruction will be given to a limited number of students interested in work to supplement that given in courses in combustion engines, power generation, fluid dynamics, heat transfer, refrigeration, air conditioning, and instruments; permission of the department necessary for registration.

3651. *GRAPHICAL SOLUTIONS*. Credit 3 hrs. Spring. 3 Rec. Elective for undergraduate students who have completed four terms or for graduate students. Design of slide rules, network charts, and alignment charts; derivation of empirical equations to fit experimental data; errors and precision of measurement.

3652. *COMBUSTION THEORY*. Credit 3 hrs. Spring. 3 Lect. Intended for graduate students but open to qualified fifth year students. Heat and mass transfer with chemical reaction; concepts of flame speed and temperature; theories of flame propagation; combustion with and without premixing; flame stability in high-velocity gas streams; combustion of liquid and solid fuels.

3661. *ADVANCED THERMODYNAMICS*. Credit 3 hrs. Fall. 3 Rec. Intended for graduate students but open to qualified fourth year students. Prereq., 3601, 3602, or equivalent. A rigorous and general treatment of the laws of thermodynamics with emphasis on mathematical development and philosophical interpretations; the pure substance; homogeneous and heterogeneous systems; Gibbs and Helmholtz functions; Maxwell relations; availability and irreversibility; equilibrium.

3662. *GAS TURBINE PLANTS*. Credit 3 hrs. Spring. 3 Lect. Prereq., 3601, 3602, or equivalent (3663 desirable). Study of the cycles and apparatus of the modern gas turbine plant; performance and suitability for various applications.

3663. *ADVANCED TURBOMACHINERY*. Credit 3 hrs. Fall. 3 Lect. Intended for graduate students but open to qualified fifth year students. Prereq., 3602, 3603, 3604, or equivalent. Transfer of energy between a fluid and a rotor; application of thermodynamics and fluid dynamics to rotating machinery; centrifugal and axial flow pumps, compressors and turbines.

3664. *THERMODYNAMICS OF FLOW OF COMPRESSIBLE FLUIDS*. Credit 3 hrs. Spring. 3 Rec. Intended for graduate students but open to qualified undergraduates. Prereq., 3602, 3604. Flow of gases with area change, friction, mass transfer, and heat transfer; Fanno and Rayleigh lines; shock phenomena. Applications to flow in ducts, diffusers, and nozzles and to design problems on compressors, turbines, ram jets, rockets, and wind tunnels.

3665. *ADVANCED HEAT TRANSFER*. Credit 3 hrs. Fall. 3 Rec. Intended for graduate students but open to qualified undergraduates. Prereq., 3605. Mechanisms of the basic modes of transfer; study of various transfer solutions and of correlations of experimental results. Analogies between transfer of heat and transfer of momentum; physical similarity; methods of approximate solution of combined mode problems; analogue techniques.

3666. *ADVANCED AIR CONDITIONING*. Credit 3 hrs. Fall. 3 Rec. Selected studies of air conditioning principles and air conditioning apparatus; solar loads and solar collectors; heat pumps; air conditioning in transportation.

3667. *TEMPERATURE MEASURING INSTRUMENTS*. Credit 3 hrs. Spring. 2 Lect. 1 Lab. Intended for graduate students but open to qualified undergraduates. Prereq., 3605. Theory, construction, calibration, and application of liquid-in-glass thermometers, solid expansion thermometers, pressure-spring thermometers, resist-

ance thermometers, thermoelectric thermometers, optical pyrometers, radiation pyrometers.

3669. *DIESEL ENGINEERING*. Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 3606, 3607. Design and construction of diesel engines, fuel injection systems, and combustion chambers; fuels and lubricants; engine governing; supercharging; experimental study of performance characteristics.

3670. *ADVANCED COMBUSTION ENGINES*. Credit 3 hrs. Spring. 1 Rec. 2 Comp. Prereq., 3607. Design and operation of combustion engines for automotive, marine, and industrial uses; special emphasis upon spark-ignition engines; matching of engine supply power and propulsion demand power. Recommended together with Course 3377 for a study of automotive engineering.

3671. *AIRCRAFT POWER PLANTS*. Credit 3 hrs. Fall. Thermal, mechanical, and operating characteristics of reciprocating and rotating aircraft power plants; studies augmented by reading of technical papers and solving problems.

3698, 3699. *PROJECT*. Total credit 6 hrs. Work of the ninth and tenth terms to integrate the training in mechanical engineering, principally in the fields of thermodynamics, fluid dynamics, heat transfer, combustion engines, power plants, refrigeration, and air conditioning.

ELECTRICAL ENGINEERING

The descriptions of courses offered in the School of Electrical Engineering follow. Courses in other divisions required of students in electrical engineering are described on pages 129-137. When, because of insufficient registration, courses cannot be given in the term for which they are scheduled, they may be given in the following term.

GENERAL COURSES

4021. *ENGINEERING REPORTS*. Credit 3 hrs. Fall. 3 Lect.-Rec. Term 7 or 9. The development of the basic principles of exposition, the knowledge of suitable form, and the appreciation of function that will enable students to write and present technical reports that meet professional standards.

4022. *ELECTRICAL ENGINEERING ECONOMY*. Credit 3 hrs. Spring. 2 Rec. 1 Comp. The principles underlying the selection of the most economical method of accomplishing an engineering objective, including interest, depreciation, return on investment, planning of plant expansion, and the theory and practice of setting rates.

4041 and 4042. *NONRESIDENT LECTURES*. Credit 1 hr. for both terms. Fall and spring. 1 Lect. Lectures given by lecturers invited from industry and from certain other departments of the University to assist students in their approach to employment and in their transition from college to industrial life.

4090. *SPECIAL TOPICS IN ELECTRICAL ENGINEERING*. Credit 1 to 3 hrs. By special arrangement with instructor.

4091 and 4092. *PROJECT*. Credit 3 hrs. Fall and spring. Individual study, analysis, and usually experimental tests in connection with a special engineering problem chosen by the student after consultation with the faculty member directing his project; an engineering report on the project is required.

BASIC ELECTRICAL ENGINEERING

4110. *PRINCIPLES OF ANALYSIS IN ELECTRICAL ENGINEERING*. Credit 3 hrs. Fall. 1 Lect. 1 Rec. 1 Comp. Prereq., Math. 162, Phys. 116. Power and energy;

measurement of electrical quantities; direct current networks and network theorems; magnetic fields and magnetic circuits; electrostatic fields and relationships in dielectrics; electromagnetic relationships; stored magnetic and electric energy; elementary transients in circuits containing resistance and either inductance or capacitance.

4111. *ELEMENTARY ALTERNATING CURRENT CIRCUITS*. Credit 3 hrs. Spring. 1 Lect. 1 Rec. 1 Comp. Prereq., Math 163, Phys. 117, 4110. Elementary a-c circuit elements; power, power factor, energy relationships; real and reactive power, application of vector algebra; series and parallel circuit elements; resonance; loci; a-c networks and network theorems; mutual inductance, coupling coefficient, leakage inductance; air and iron core transformers and vector diagrams.

4112. *ALTERNATING CURRENT NETWORKS*. Credit 3 hrs. Fall. 1 Lect. 1 Rec. 1 Comp. Prereq., Math 607, 4111. Polyphase circuits and power measurement; phase sequence effects; balanced and unbalanced conditions; nonsine waves in polyphase systems; four terminal network; A, B, C, D, constants, open and short circuit impedances; image impedances, and transfer constants; the concept of a complex frequency; problems involving the complex frequency plane.

4113. *TRANSMISSION LINES AND FILTER NETWORKS*. Credit 3 hrs. Spring. 1 Lect. 1 Rec. 1 Comp. Prereq., 4112. Steady state solution, characteristic impedance and propagation constant; reflection coefficient; vector diagrams; impedance charts as graphical aids; transmission line networks; impedance transformations; network image and iterative operation, transfer constants; constant K, m derived, and lattice types; Foster's theorem; Bartlett's theorem; composite filter design; wave guides; transmission line analogue in solution of guide problems; modes; impedance transformations.

4114. *TRANSIENTS IN LINEAR SYSTEMS*. Credit 3 hrs. Fall. 1 Lect. 1 Rec. 1 Comp. Prereq., 4112. Transient behavior of circuits with lumped constants; the classical solution of single- and double-energy circuits in the transient state; the ordinary linear differential equation; the Laplace transformation; systems of ordinary linear differential equations, their Laplace transformation, and their solution.

4115. *PRINCIPLES OF NONLINEAR CIRCUITS*. Credit 3 hrs. Spring. 3 Rec. Prereq., 4114. Foundations of electrical nonlinear circuits. Methods of nonlinear analysis: Graphical, piecewise linear approximations, nonlinear mechanics and topological aspects of phase spaces; fundamental concepts of pulse and control circuits with reference to radar, pulse communication, television, computers, instrumentation, servomechanisms, and automatic control.

4116. *ELECTRIC CIRCUIT LABORATORY*. Credit 3 hrs. Fall. 1 Lect. 1 Lab. Prereq., 4111 or 4983. D-c circuits and parameters; d-c bridges; temperature measurements; heat flow; instruments; calibration and standards; transients.

4121. *ELECTRON TUBES AND CIRCUITS*. Credit 4 hrs. Spring. 2 Lect.-Rec. 1 Comp. 1 Lab. Prereq., 4116 and either 4112 or 4983. Emission; conduction in high vacuum and gas; cathode-ray tubes; high-vacuum, crystal, and thermionic gas diodes; cold-electrode gas-discharge tubes; rectification and filtering; thyratrons, pool-type tubes, polyphase rectifiers, and electronic light sources; high-vacuum triode characteristics, parameters, and equivalent circuits.

4122. *ELECTRONIC CIRCUIT ELEMENTS*. Credit 4 hrs. Fall. 3 Lect.-Rec. 1 Lab. Prereq., 4121. Multigrid vacuum-tube characteristics, parameters, and equivalent circuits; transistor characteristics, parameters, and equivalent circuits; application of linear equivalent circuits in devices using high-vacuum tubes and transistors; studies of air-core and iron-core transformers as used in communication systems; studies of small-signal and large-signal amplifiers using high-vacuum tubes and transistors.

4123. *ELECTRONIC CIRCUIT ELEMENTS*. Credit 4 hrs. Spring. 3 Lect.-Rec. 1 Lab. Prereq., 4113, 4114, 4122. Studies of feedback systems using positive and negative feedback; amplitude and angular modulation and demodulation; multivibrators and blocking oscillators; simple wave-shaping circuits; elements of electronic computers.

4216. *ELECTRICAL MACHINERY LABORATORY*. Credit 4 hrs. Spring. 1 Lect. 1 Rec. 1 Lab. Prereq., 4116. D-C magnetization; d-c motors; d-c controllers; d-c generators; amplidyne; loss separation; a-c magnetization; a-c bridges.

4221. *ALTERNATING CURRENT MACHINERY*. Credit 4 hrs. Fall. 1 Conf. 1 Comp. Prereq., 4112, 4216. Theory, construction and operating characteristics of transformers, induction motors, synchronous machines, and single-phase motors.

4226. *ELECTRICAL MACHINERY LABORATORY*. Credit 4 hrs. Spring. 1 Lect. 1 Rec. 1 Lab. Prereq., 4221. Magnetization and circuits with nonsinusoidal voltages. Harmonics in polyphase systems; instrument, constant current and constant potential transformers; single-phase and polyphase induction motors; synchronous machines.

POWER SYSTEMS AND MACHINERY

4321. *ELECTRICAL MACHINE THEORY*. Credit 3 hrs. Fall. 1 Conf. 1 Comp. Prereq., 4226. Space harmonics; parasitic torques; two-reaction analysis; transient impedances; symmetrical component impedances; single-phase motor analysis; commutator-type a-c machines.

4326. *ELECTRICAL MACHINERY LABORATORY*. Credit 3 hrs. Spring. 1 Lect. 1 Lab. Prereq., 4321. Salient-pole synchronous machines; induction motor loss separation; energy metering; special topics.

4351. *POWER SYSTEMS I*. Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab.-Comp. Prereq., 4113, 4226, or equivalent. Steady-state performance of electric power systems; steady-state electrical characteristics and equivalent circuit elements of static loads, rotating machines, transformers, and transmission circuits; steady-state circuit analysis of the power system network with the aid of the network analyzer; control and regulation of the power system to maintain normal operating conditions; use of digital and analogue computing devices.

4352. *POWER SYSTEMS II*. Credit 3 hrs. Spring. 2 Lect.-Rec. 1 Lab.-Comp. Prereq., 4114, 4226 and 4351, or equivalent. Transient analysis of electric power systems, especially the transients of electromagnetic quantities; characteristics of rotating machines; systems of components used in power system analysis; justification of quasi-steady-state analysis; use of a-c network analyzers, and electronic differential analyzers in computation.

4353. *POWER SYSTEMS III*. Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab.-Comp. Prereq., 4351, and 4352, or equivalent. Electromechanical transients of power systems; protective schemes against abnormal operation of power systems; large-amplitude, and the small-amplitude swing or oscillation of the synchronous machine rotors; analytical methods in the understanding of the physical phenomena; analysis of protection and control schemes of the power system during abnormal operation.

4371. *HIGH-VOLTAGE PHENOMENA*. Credit 3 hrs. Spring. Prereq., 4351. The study of problems of the normal operation of power systems at very high voltages, of the abnormal conditions imposed by lightning, of the methods employed to assure proper operation of power systems and apparatus under high-voltage conditions, and of the devices available for laboratory testing of equipment under actual or simulated conditions.

INDUSTRIAL ELECTRONICS

4411. *ELECTRONIC CONTROL EQUIPMENT*. Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 4123. Principles of electronic instrumentation and electronic control systems; methods of utilizing a stimulus in the form of heat, light, sound, or mechanical motion; industrial circuits including timing circuits, photoelectric controls, motor controls, welder controls, voltage regulators and frequency-varying and frequency-discriminating circuits. Development of original thinking and methods of investigation.

4415. *ADVANCED ELECTRONIC CONTROLS*. Credit 3 hrs. Spring. 2 Lect. 1 Lab.-Comp. Prereq., 4411. An advanced study of the theory, design and characteristics of selected electronic units.

4421. *ELECTRONIC POWER CONVERTERS*. Credit 3 hrs. Spring. 2 Lect. 1 Lab.-Comp. Prereq., 4411. Study of oscillators, mercury-pool rectifiers, and inverters in power sizes covering practical circuits, complete laboratory tests, and comprehensive mathematical treatments.

RADIO AND COMMUNICATION

4501. *RADIO AND COMMUNICATION SEMINAR*. Credit 1 to 3 hrs. Fall and spring. Primarily for graduate students. Reading and discussion of technical papers and publications in the field of radio and communication.

4511. *RADIO AND COMMUNICATION THEORY*. Credit 3 hrs. Fall. 3 Lect. Prereq., 4113, 4114, and 4123. Study of the transient and steady-state response of circuits; consideration of noise in communication systems; elements of information theory; illustrative examples from fields of television, radar, and computers.

4512. *RADIO AND COMMUNICATION THEORY*. Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereq., 4113, 4123. A study of communication circuits with distributed constants and the production and propagation of electromagnetic radiation; transmission line theory and applications; impedance matching; ultra-high-frequency generation and transmission; electromagnetic theory; propagation phenomena; antenna characteristics and radiation.

4516, 4517. *RADIO AND COMMUNICATION LABORATORY*. Credit 3 hrs. each. Fall and spring respectively. Either or both may be taken. 1 Rec. 1 Lab. Prereq., 4113 and 4123. Choice of three to five different experiments from the fields of electronic circuits, networks, transmission lines; wave guides, and antennas; experiments selected to meet individual needs.

4518. *COMMUNICATION EQUIPMENT SHOP*. Credit 1 hr. Fall. 1 Lect.-Lab. Prereq., 4123. Construction and test of an electronic device; study of circuit components in terms of their application in electronic circuits; the use of hand tools; circuit layout in accordance with good construction practice.

4526. *ELECTRON DYNAMICS*. Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 4122. Study of the fundamental theory of low frequency electron devices. Emission theory, conformal mapping techniques, particle dynamics, electrostatic and magnetic lenses; space charge phenomena in diodes, triodes and dense electron beams; limitations of low frequency devices at high frequencies; noise in vacuum tube circuits.

4527. *MICROWAVE ELECTRONICS*. Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 4122. Study of the theory of high frequency electron devices. Electron-electromagnetic field interaction theory for diodes, klystrons, traveling-wave tubes, Carcinotrons and magnetrons.

4529. *TRANSISTORS*. Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., Phys. 214 and

4123. Motion of electrons and holes in semiconductors; the physical basis of transistor action and semiconductor rectifiers; application of transistors and semiconductor rectifiers as active or passive elements in circuits for use as amplifiers, oscillators, modulators, switches, photoelectric devices, and other circuits.

4531. *TELEVISION SYSTEMS*. Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 4511. Basic work in transient analysis, vacuum tube amplifiers, cathode-ray pickup and viewing tubes, cathode-ray beam deflection, pulse shaping, modulation, and antenna characteristics; further study of television problems; optics, illumination, color vision, scanning, synchronization, blanking, and shading are considered.

4541. *APPLIED ACOUSTICS*. Credit 2 hrs. Fall. 2 Lect.-Rec. Prereq., 4123. The laws of ideal gases, the thermodynamic properties of air, and the laws of the propagation of compressional waves; the transmission of sound through tubes, horns, and unbounded media; the design of sound sources, microphones, loudspeakers, and wax, lacquer, magnetic, and photographic recorders; reflection, absorption, and reverberation.

4551. *RADIO AIDS TO NAVIGATION*. Credit 2 hrs. Spring. 2 Lect.-Rec. Prereq., 4123. Long-wave and medium-wave direction finders and radio beacons; atmospheric effects and limitations on accuracy; medium-frequency pulsed transit-time systems and high-frequency return-signal systems, with application to long-range navigation and precision mapping; airport approach systems and traffic control.

4561. *MICROWAVE COMPONENTS AND TECHNIQUES*. Credit 2 hrs. Spring. 2 Lect. Prereq., 4565 and 4512. Should be accompanied by 4517. Electrical equipment particularly applicable to microwave operation; magnetrons, klystrons, and other similar generators; measuring devices; transmission systems; wave guides, coaxial lines, and cavity resonators.

4563. *PULSE TECHNIQUE IN COMMUNICATION AND RADAR*. Credit 3 hrs. Fall. 3 Lect. Prereq., 4114 and 4123. Analysis of signal functions; noise analysis; basic principles of pulse generation, modulation, transmission, and reception; fundamental circuits of pulse techniques; application to radar; pulse communication systems, known as pulse-amplitude, pulse-time, pulse-position, and pulse-code modulating systems.

4564. *TRANSMISSION OF INFORMATION*. Credit 3 hrs. Spring. 3 Lect. Prereq., 4563. The statistical properties of the source; the transformation of primary signal functions into secondary signal functions at the transmitter; the capacity of the channel to transmit the secondary signal function in the presence of channel noise; the possibilities of recovering the primary signal function at the receiver; pulse-code modulation.

4565. *ELECTROMAGNETIC THEORY*. Credit 3 hrs. Fall. 3 Lect. Prereq., Phys. 117. The foundations of electromagnetic theory required for study of radio wave propagation; a critical examination of the significance of the electromagnetic vectors and their relations to a discussion of the principles involved in guided and unguided propagation.

4566. *RADIO WAVES I*. Credit 3 hrs. Spring. 3 Lect. Prereq., 4565. Influence of the earth, the lower atmosphere, and the ionosphere on propagation of radio waves; the Sommerfeld theory: propagation in an ionized atmosphere; reflection from the ionosphere at both normal and oblique incidence.

4567. *RADIO WAVES II*. Credit 3 hrs. Fall. 3 Lect. Prereq., 4566. The influence of the earth's magnetic field upon ionospheric propagation; diffraction round a spherical earth; propagation in standard and nonstandard atmospheres; scattering.

4568. *ANTENNAS*. Credit 3 hrs. Spring. 3 Lect. Prereq., 4565. The theory of radiation and reception by dipoles, slots, broadside antennas, end-fire antennas, horns, and paraboloids; the detailed electromagnetic field of simple antennas.

4571. *ADVANCED COMMUNICATION NETWORKS*. Credit 3 hrs. Spring. 3 Lect. Prereq., 4113. Mesh and nodal analysis; the complex frequency plane; conditions for physical realizability; representation of driving-point and transfer impedance functions by physical networks; topics in the design of impedance functions.

ILLUMINATION

4611. *INTRODUCTORY ILLUMINATION*. Credit 3 hrs. Fall. 2 Rec. 1 Lab. Comp. Prereq., Phys. 118. Problems commonly encountered in illumination engineering and the methods of solution; sources of light; visual perception; light control, both spectral and directional; measurement of light sources and illumination; general illumination design; production and mixing of colors; architectural objectives.

4612. *ILLUMINATING ENGINEERING*. Credit 3 hrs. Spring. 2 Rec. 1 Lab.-Comp. Prereq., 4611. Computation of light-flux distribution and study of difficult lighting problems; emphasis on specialized rather than general lighting problems.

4615. *ILLUMINATION SEMINAR*. Credit 2 hrs. Fall. 1 two-hour period each week. Must be accompanied or preceded by 4611. Reports on selected topics of current interest in illuminating engineering.

SERVOMECHANISMS

4711. *SERVOMECHANISM I*. Credit 3 hrs. Fall. 2 Lect. Rec. 1 Lab.-Comp. Prereq., 4123, 4216, 4221, 4226. Principles of servomechanisms, emphasizing analysis of performance from equations and transfer-function plots; Laplace transformations, error detecting devices; hydraulic devices; factors affecting errors, damping, and speed of response; criteria for stability.

4712. *SERVOMECHANISM II*. Credit 3 hrs. Spring. 2 Lect.-Rec. 1 Lab.-Comp. Prereq., 4711. Synthesis of feedback control systems; prediction of performance from stability criteria and comparison with laboratory performance.

4713. *SERVOMECHANISMS SEMINAR*. Credit 2 hrs. Fall. 1 two-hour period. Prereq., 4712. Reports on selected topics in servomechanisms; nonlinear effects on analysis and performance; sampled data systems; power requirements, analogue computers for servo analysis and synthesis; statistical analysis of servomechanisms.

COMPUTERS

4810. *INTRODUCTION TO ELECTRONIC COMPUTERS*. Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab. Prereq., 4114 and 4123. An introduction to the field of electronic computing devices, their philosophy, operation, design, principles, and use; detailed treatment of analogue computers; brief discussion of digital and other computers.

4820. *SWITCHING THEORY FOR DIGITAL COMPUTERS*. Credit 3 hrs. Spring. 2 Lect.-Rec. 1 Lab. Prereq., 4113, 4121. An introduction to the theory and design of switching circuits; discussion of elements used in switching apparatus; detailed consideration of switching algebra and its application to switching circuits.

COURSES FOR OTHER ENGINEERING CURRICULA

4931. *ELECTRICAL ENGINEERING*. Credit 3 hrs. Fall and spring. 1 Lect. 1 Rec. 1 Comp. Prereq., Math. 163, Mech. 1132 or 1152. An elementary study of direct-current electric circuits; the concepts of resistance, inductance, and capacitance; magnetic circuits; single-phase and three-phase alternating-current circuits; instruments and techniques appropriate for making measurements in all such circuits.

4932. *ELECTRICAL ENGINEERING*. Credit 3 hrs. Fall and spring. 1 Lect. 1 Rec. 1 Lab.-Comp. Prereq., 4931. D-C generators and motors; motor starters and controllers; transformers; induction motors; synchronous machines; a-c single-phase motors; d-c and a-c selsyn units.

4933. *ELECTRICAL ENGINEERING*. Credit 3 hrs. Fall and spring. 1 Lect. 1 Rec. 1 Lab.-Comp. Prereq., 4932. The characteristics and applications of the various commonly used electron tubes; rectifiers; amplifiers; oscillators: electronic control and instrumentation.

4934. *PRINCIPLES OF AUTOMATIC CONTROL*. Credit 3 hrs. Spring. 1 Lect. 1 Rec. 1 Lab. Prereq., 4933. The mathematics of automatic control as exemplified in servo devices, with analysis of electrical, mechanical, and hydraulic applications; problems of electrical instrumentation in automatically controlled operations and processes.

4983. *BASIC ELECTRICAL ENGINEERING*. Credit 4 hrs. Spring. 1 Lect. 2 Rec. 1 Comp. Prereq., Math. 163, Phys. 117. Capacitors; simple electrical transients. Direct-current and alternating-current circuits, magnetic circuits including permanent magnetic material.

4991. *ELECTRONIC CIRCUITS*. Credit 3 hrs. Fall. 3 Lect. For graduate students majoring in an engineering field other than electrical. Alternating-current circuits; characteristic of high-vacuum tubes and transistors; small-signal and large-signal amplifiers; feedback and oscillators; modulation and demodulation; simple wave-shaping circuits.

CHEMICAL ENGINEERING

5000. *ORIENTATION*. No credit. Fall and spring. 1 Lect. Both terms required of all freshmen.

5101, 5102. *INTRODUCTORY CHEMICAL ENGINEERING*. Credit 2 hrs. Fall and spring. 2 Lect. Prereq., Chemistry 111, 112. An introduction to the processes and calculations of chemical engineering.

5103. *CHEMICAL ENGINEERING THERMODYNAMICS*. Credit 3 hrs. Fall. 3 Lect. Prereq., Chemistry 403, 404. The development of the fundamental principles of thermodynamics, with special attention to their application to chemical engineering processes.

5104. *CHEMICAL ENGINEERING THERMODYNAMICS*. Credit 3 hrs. Spring. 3 Lect. Prereq., 5103. Continuation of 5103.

5106. *REACTION KINETICS AND REACTOR DESIGN*. Credit 2 hrs. Fall. 2 Lect. Prereq., 5104. A study of chemical reaction kinetics and principles of reactor design for chemical processes.

5203, 5204. *CHEMICAL ENGINEERING TECHNOLOGY*. Credit 2 hrs. Fall and spring. 2 Lect. A discussion of the important chemical engineering processes and industries. First term, inorganic chemical technology; second term, organic chemical engineering industries.

5303, 5404. *UNIT OPERATIONS*. Credit 3 hrs. Fall and spring. 3 Lect. Prereq. or parallel, Chemistry 403 and Engineering 5203 and 5204. A critical discussion of the unit operations of chemical engineering.

5312. *SPECIALIZED UNIT OPERATIONS*. Credit 3 hrs. Spring. Prereq., 5304. Lectures and problems in adsorption, ion exchange, chromatography, flow under high vacuum and other unit operations used particularly for the processing of foods, pharmaceuticals, and fine chemicals. Given in alternate years.

5353, 5354. *UNIT OPERATIONS LABORATORY*. Credit 3 hrs. Fall and spring. Prereq., 5303, 5304.

5503, 5504. *CHEMICAL ENGINEERING COMPUTATIONS*. Credit 2 hrs. Fall and spring. 2 class periods. Prereq. or parallel, 5304. Problems in fluid flow and heat transfer; distillation; evaporation; drying; humidification and air conditioning; and filtration.

5505. *ADVANCED HEAT TRANSFER*. Credit 2 hrs. Spring. Prereq., 5303-4 or equivalent. Advanced topics in heat transfer. Heat transfer under unsteady-state conditions; numerical approximation methods; analogies among heat, mass, and momentum transfer; heat transfer to liquid metals; simultaneous heat and mass transfer, etc. Primarily for graduate students.

5506. *DIFFUSIONAL OPERATIONS*. Credit 3 hrs. Fall. 3 class periods. Prereq., 5503, 5504, or equivalent. Primarily for graduate students. Advanced topics in distillation; gas absorption; liquid-liquid extraction; and drying.

5603, 5604. *CHEMICAL ENGINEERING EQUIPMENT*. Credit 2 hrs. Fall and spring. 2 Lect. Prereq., 5304. Details of design and construction of chemical engineering equipment; piping; design of pressure vessels; detailed design of process equipment.

5605, 5606, 5607, 5608. *DESIGN PROJECT*. Credit 2 hrs. Fall and spring. Individual problems in the design of complete chemical plants, with estimation of costs of construction and operation, market surveys for raw materials and finished products, and profitable profit from operations.

5701. *PLANT INSPECTIONS*. Credit 1 hr. Spring. A series of supervised inspection trips to manufacturing plants representing various chemical engineering industries.

5711. *LIBRARY USE AND PATENTS*. Credit 1 hr. Fall. The effective use of technical literature; literature searches; abstracts and bibliographies; patent law.

5741. *PETROLEUM REFINING*. Credit 3 hrs. Spring. 3 Lect. Prereq., 5304. Processes employed in petroleum refining.

5742. *POLYMERIC MATERIALS*. Credit 3 hrs. Fall. Prereq., Chemistry 404. Polymerization reactions, manufacture and properties of synthetic resins, fibers, plastics, and rubbers.

5743. *ADVANCED POLYMERIC MATERIALS*. Credit 2 hrs. Spring. Prereq., 5742. Special topics involving rubbers, fibers, and plastics.

5745. *STATISTICAL METHODS IN PROCESS INDUSTRIES*. Credit 3 hrs. Fall. 3 Lect. Prereq., 5304 and 5354, or 6204 and 6254. The methods used for operation control and quality control in chemical engineering processes.

5746. *CHEMICAL ENGINEERING ECONOMICS*. Credit 3 hrs. Fall. 3 Lect. Prereq., 5304, or special permission. The economic aspects of research, development, manufacturing, and sales in the chemical industries.

5747. *PROCESS CONTROL*. Credit 2 hrs. Spring. 2 Lect. Prereq., 5304. Types

of control instruments used in process industries; response characteristics of controllers. Response characteristics of processes. Selection of controllers for desired over-all characteristics. Design of processes for controllability.

5748. *FERMENTATION ENGINEERING*. Credit 3 hrs. Spring. 3 Lect. Prereq., Chemistry 404 or 408. An advanced discussion of fermentation as a unit process. Topics include sterilization, aeration, agitation, and continuous fermentation.

5749. *INDUSTRIAL MICROORGANISMS*. Credit 1 hr. Fall. 1 Lect. Prereq., organic chemistry and physical chemistry. A brief introductory course in microbiology for students with a good background in chemistry. Text: Clifton's *Introduction to the Bacteria*.

5760. *NUCLEAR AND REACTOR ENGINEERING*. Credit 2 hrs. Spring. 2 Lect. Fuel processing and isotope separation, radioactive waste disposal, fuel cycles, radiation damage, biological effects and hazards, shielding, power reactors.

5851. *CHEMICAL MICROSCOPY*. Credit 3 hrs. Either term. 1 Lect. and 2 Lab. periods. Prereq., or parallel courses, Chemistry 403, 404, or 407, 408 and Physics 117, 118, or special permission. The use of microscopes and their accessories in chemical and technical investigations. Micrometry; quantitative estimations; microscopical characteristics and physical chemistry of crystals; lens systems and photomicrography; study of industrial materials.

5853. *MICROSCOPICAL QUALITATIVE ANALYSIS (INORGANIC)*. Credit 2 hrs. or more. Either term. Prereq., 5851. Laboratory periods to be arranged. Laboratory practice in the analysis of inorganic substances containing the more common elements.

5859. *ADVANCED CHEMICAL MICROSCOPY*. Credit 1 hr. or more. Either term. Prereq., 5851 and special permission. Laboratory practice in special methods and special applications of chemical microscopy.

5953, 5954. *RESEARCH PROJECT*. Credit 2 hrs.; additional credit by special permission. Fall and spring. Prereq., 5304. Research on an original problem in chemical engineering.

5955, 5956. *SPECIAL PROJECTS IN CHEMICAL ENGINEERING*. Credit variable. Either term. Prereq., 5954. Research or studies of special problems in chemical engineering.

METALLURGICAL ENGINEERING

6000. *ORIENTATION*. No credit. Fall and spring. 1 Lect. Both terms required of all freshmen.

6103. *METALLURGICAL ENGINEERING THERMODYNAMICS*. Credit 3 hrs. Fall. 3 Lect. Prereq., Chemistry 403, 404. The development of the fundamental principles of thermodynamics and the application of these principles to chemical systems of metallurgical interest. Particular attention is given to standard states and to experimental methods used in metallurgical investigations.

6110. *CASTING, WORKING, AND WELDING OF METALS*. Credit 2 hrs. Either term. 1 Lect. and 1 lab. period. An elementary course covering the important industrial processes used in the casting, hot working, cold forming, and welding of metals. The utilization of metallurgical processes in other branches of engineering is stressed.

6111. *INTRODUCTORY METALLURGY*. Credit 2 hrs. Fall. 1 Lect. and 1 lab. period. For students in metallurgical engineering. An introduction to the principles

of metallurgy. Covers a number of metallurgical processes and includes laboratory work in casting, metal working, welding, and heat treatment.

6112. *METALLURGY OF CASTING, WORKING, AND WELDING*. Credit 2 hrs. Spring. 2 Lect. Prereq., 1231, 6110. An advanced course for students in mechanical engineering covering the application of metallurgical principles to foundry, metal working, and welding problems.

6114. *METALLURGY OF CASTING, WORKING, AND WELDING*. Credit 2 hrs. Spring. 3 Lect. and 1 lab. period. Prereq., 6111, 6811. For students in metallurgical engineering. A critical study of selected processes in the fields of casting, metal forming and working, welding, and power metallurgy. Emphasis is placed on the metallurgy principles involved, the metallurgical factors governing control of the processes, and the influence of the processing methods on the final products.

6120. *ADVANCED FOUNDRY ENGINEERING*. Credit 3 hrs. Fall. 3 class periods including special laboratory studies. Prereq., 6113 or 6114. Critical study of foundry technology and the metallurgical features of cast metals. Laboratory investigation of special foundry processes and procedures.

6203, 6204. *SMEETING AND REFINING*. Credit 3 hrs. Fall and spring. 3 Lect. Prereq., 6501. Methods of extraction of metals and alloys of commerce. Consideration is given to principles of ore beneficiation and to fundamentals of metallurgical practice, including details of production and utilization of heat. The commercial processes for the reduction and refining of individual metals together with limitations and problems arising from these processes are analyzed. A detailed consideration of the furnace operations in the manufacture of iron and steel illustrates the application of physicochemical principles to the industrial production of useful alloys.

6221. *ADVANCED PROCESS METALLURGY*. Credit 3 hrs. Spring. Prereq., 6103, 6203, 6204. Application of thermodynamic principles to chemical systems of metallurgical interest. Consideration is given to the thermodynamics of phase equilibria in alloy systems as well as to reactions which occur in smelting and refining.

6223. *STEEL-MILL PRODUCTS*. Credit 2 hrs. Fall. 2 Lect. Prereq., consent of instructor. Engineering, scientific, and economic factors involved in the production of iron and steel, including alloy steels. The production of structural sections, plate, strip, tinplate and other steel mill products.

6224. *PHYSICAL CHEMISTRY OF METALLURGICAL REACTIONS*. Credit 2 hrs. Spring. 2 Lect. Prereq., consent of instructor. A study of the physical chemistry of reactions involved in the reduction, refining, heat treating, and utilization of metals and alloys.

6253, 6254. *UNIT PROCESSES IN METALLURGY*. Credit 3 hrs. Fall and spring. 1 Lect. and 1 lab. period with reports. Prereq., 6203, 6204. Experimental study of important processes in metallurgy, including ore dressing, temperature measurements, generation and control of furnace atmospheres, furnace design and performance, smelting and refining operations and electrodeposition. Reports based on the experimental data, discussing the principles involved in the operations, are an important part of the course.

6255, 6256. *MATERIALS OF CONSTRUCTION*. Credit 3 hrs. each term. 3 Lect. Prereq. or parallel courses, Physical Chemistry 403, 404. An introductory presentation of the nature, properties, treatment, and applications of the more important metals and alloys, including extractive and physical metallurgy and behavior under service conditions. Nonmetallic materials, including refractories, cement, protective coatings, and plastics, are also discussed.

6311, 6312. *PHYSICAL METALLURGY*. Credit 2 hrs. Fall and spring. Prereq., 6811. Detailed discussion of plastic deformation, recrystallization and grain growth, diffusion in alloys, precipitation from solid solution, and transformation mechanisms in heat treatment.

6351. *PHYSICAL METALLURGY LABORATORY*. Credit 3 hrs. Fall. Labs. with conferences. Parallel, 6311. Theory and metallurgical application of X-ray diffraction, and experiments to illustrate the important phenomena of physical metallurgy and techniques for their investigation. Determination of lattice types, parameter measurements, pole figures, and single crystal orientation by X-ray methods.

6352. *METALLURGY RESEARCH TECHNIQUES*. Credit 3 hrs. Spring. 1 Lect. 5 hrs. of lab. each week. Advanced laboratory procedures in experimental metallurgy. Includes specialized X-ray diffraction techniques, electron diffraction, fractography, calorimetry, and dilatometry. Radioactive tracer techniques for diffusional studies are included. Vacuum techniques for melting, degassing, cathodic vacuum etching, etc. are extensively studied. Measurement of strain rates and crack propagation at low and high temperatures are considered.

6371. *PRINCIPLES OF POWDER METALLURGY*. Credit 3 hrs. Fall. 2 Lect. and one 2½-hour lab. each week. Following brief consideration of industrial powder-metallurgy equipment, including dies, presses, and sintering furnaces, and industrial applications such as porous products, permanent magnets, refractory metals, cemented carbides, cermets, etc., the theory of powder metallurgy is treated critically. Emphasis is on the theories of compacting and sintering, diffusional effects, and surface chemistry. The theories, applications, and limitations of hot pressing are examined critically. Laboratory experimentation is primarily concerned with fundamental investigation of compacting, bonding, sintering, hot pressing, infiltration of porous networks, etc. Laboratory studies of surface chemistry and surface activation are included.

6501. *METALLURGICAL CALCULATIONS*. Credit 2 hrs. Fall. 2 class periods. Prereq., 6111. An introductory course in the application of the principles of chemistry and physics to metallurgical problems, including combustion, heat balances, gas reactions, and furnace changes.

6602. *METALLURGICAL DESIGN*. Credit 3 hrs. Spring. 3 class periods. Prereq., 6312. Metallurgical and mechanical factors governing the selection of metals for various services. Analysis of service requirements, and the selection and fabrication of metals to fulfill such requirements; analysis of service failures of metals and remedies for such failures; and study of the merits and limitations of materials applications in existing products and equipment.

6701. *PLANT INSPECTION*. Credit 1 hr. Spring. A series of supervised inspection trips to manufacturing plants representing various metallurgical engineering industries. Each student is required to submit a comprehensive report.

6811. *INTRODUCTORY METALLOGRAPHY*. Credit 3 hrs. Spring. 1 Lect. and 2 lab. periods. Prereq., 6255, or consent of instructor. Microstructures of alloys, as related to composition, thermal history, and physical properties. Preparation of specimens; principles and use of metallographic microscopes.

6841. *CERAMICS*. Credit 2 hrs. Fall. 2 Lect. Prereq., consent of instructor. Physical chemistry, structure, and behavior of ceramic materials in technology.

6851. *ALLOY STEELS*. Credit 2 hrs. Lect. Fall. Prereq., consent of instructor. Study of the basic effects of alloying on the structure and properties of steels, and the application of this knowledge to the design of modern high-strength, stainless, or heat-resistant steels and of steels for tools and dies.

6862. *METALS AT LOW AND HIGH TEMPERATURES*. Credit 2 hrs. Lect.

Fall. Prereq., consent of instructor. Evaluation and application of metals for use at service temperatures. Emphasis is placed on nature of creep flow and fracture at elevated temperatures and of notch brittleness at low temperatures. Attention is also paid to scaling, metallurgical instability, and various physical properties.

6953, 6954. *SENIOR PROJECT*. Credit 2 hrs. Fall and spring. Prereq., 6254. Research on an original problem in metallurgical engineering.

6960. *SEMINAR IN PHYSICAL METALLURGY*. For graduate students. Fall and spring. Hours to be arranged. Diffusion, nucleation and growth, precipitation from solid solution, eutectoid decomposition, diffusionless transformations, recovery, recrystallization and grain growth, order-disorder, radiation effects.

6970. *SEMINAR IN PHYSICAL CHEMISTRY OF METALS*. For graduate students. Fall and spring. Physical chemistry of metallurgical reactions with emphasis on reduction and refining, gas-liquid metal-slag reactions, thermodynamics of phase equilibria and interfaces, phase stability, electrochemistry, oxidation and corrosion.

AERONAUTICAL ENGINEERING

7001. *INTRODUCTION TO AERONAUTICAL ENGINEERING*. Credit 3 hrs. Given as required. Prereq., engineering mechanics. An introductory course for undergraduate students in all branches of engineering. Emphasis on airplane mechanics; aerodynamic forces; airplane performance, airplane stability and control.

7101. *MECHANICS OF AIRPLANES*. Credit 3 hrs. Fall. Prereq., engineering mechanics. Physics of the atmosphere, properties of gases and fluids; similarity laws. Inviscid incompressible flow; momentum methods; vortices; introduction to airfoil and wing theory. Basic properties of compressible flow at subsonic, transonic, and supersonic speeds. Introduction to the methods of viscous flow theory; viscous drag; experimental methods. Estimation of airplane performance. Static longitudinal stability and control, stick-fixed and stick-free, power effects.

7102. *MECHANICS OF AIRPLANES*. Credit 3 hrs. Spring. Prereq., 7101. Dynamics of longitudinal motion; phugoid motion; longitudinal stability, stick-fixed and stick-free; stability criteria. Lateral dynamics; discussion of derivatives: lateral stability, controls fixed and free; discussion of modes. Autorotation and spin. Response to controls; operational methods; automatic stabilization and autopilot.

7203. *GASDYNAMICS I*. Credit 3 hrs. Fall. Prereq., engineering thermodynamics. Cycle thermodynamics; the gas-turbine process. Thermodynamics of flow. Cycle and analysis of turbojets, ramjet, turboprop, ducted-fan, afterburner, etc. Heat transfer by force convection at high speeds; gas properties. Reynolds' analogy. One-dimensional steady flow of a perfect gas with heat addition, shock waves, etc. Elements of the jet-propulsion engine; combustion chamber; aerodynamic design of compressors and turbines. Rockets.

7204. *GASDYNAMICS II*. Credit 3 hrs. Spring. Prereq., 7203 or 8121. Wave-propagation phenomena, method of characteristics for 2-dimensional and axisymmetric supersonic steady flow and unsteady channel flow. Experimental methods. Hypersonic flow phenomena, flow of real gases, and magneto-hydrodynamics.

7206. *SPECIAL TOPICS IN PHYSICAL GASDYNAMICS*. Credit 2 hrs. Given as required. Prereq., 8121, 8122, or equivalents, and 7204. A study of various gasdynamical problems in which the molecular kinetics plays an important role. Specific topics to be chosen by consultation.

7301. *THEORETICAL AERODYNAMICS I*. Credit 3 hrs. Six hours a week during the first half of the fall term. Prereq., differential equations, intermediate mechanics

or introduction to theoretical physics. Introduction to theoretical hydrodynamics. Ideal fluids. The boundary-value problems of steady and nonsteady two- and three-dimensional potential flows with special attention to flows produced by the motion of solid bodies. Vector methods and complex variable are used extensively.

7302. *THEORETICAL AERODYNAMICS II*. Credit 3 hrs. Spring. Prereq., 7301, 7303. Wing theory; thin-airfoil theory, two-dimensional airfoil theory. Prandtl wing theory, lifting surfaces, general multiple theory, nonstationary wing theory. Correction for compressibility (linearized theory). Wing theory for supersonic speeds; source and sink methods and extensions, conical-flow methods, nonstationary cases.

7303. *THEORETICAL AERODYNAMICS III*. Credit 3 hrs. Six hours a week during the second half of the fall term. Prereq., 7204, 7301. The aerodynamics of compressible fluids; equations of motion, small-perturbation theory (subsonics and supersonic); Janzen-Rayleigh theory, the hodograph methods, the limiting line, the method of characteristics, Prandtl-Meyer flow, hypersonic flow.

7304. *THEORETICAL AERODYNAMICS IV*. Credit 3 hrs. Spring. Prereq., 7301. The aerodynamics of viscous fluids; the boundary layer, heat transfer, fundamentals of boundary-layer stability. Turbulence, the fundamentals of isotropic turbulence. Experimental methods.

7306. *THEORY OF PROPELLERS AND ROTORS*. Credit 1 hr. Spring. Prereq., 7101 or equivalent. Momentum and blade-element theories. Glauert-Betz theory of lightly loaded propellers and other theories; two-dimensional cascades; application to compressors; fans and turbines; application to helicopters.

7403. *AIRPLANE DESIGN*. Credit 1 hr. Fall. Orientation: the airplane and its components; the philosophy of airplane design; aircraft materials and processes.

7404. *AIRPLANE DESIGN*. Credit 1 hr. Spring. Prereq., 7403. Orientation (continued).

7405. *AERO-ELASTIC PROBLEMS*. Credit 3 hrs. Spring. Prereq., 7101 and strength of materials. Wing divergence and aileron reversal for straight and swept wings. Gust loads on the elastic airplane. Flutter calculations. Discussion of flutter modes involving control-surface vibration.

7801. *RESEARCH IN AERONAUTICAL ENGINEERING*. (Credit to be arranged.) Prereq., admission to the Graduate School of Aeronautical Engineering and approval of the Director. Independent research in a field of aeronautical science. Such research must be under the guidance of a member of the staff and must be of a scientific character.

7901. *AERONAUTICAL ENGINEERING COLLOQUIUM*. Credit 1 hr. Prereq., admission to the Graduate School of Aeronautical Engineering. Lectures by staff members, graduate students, personnel of Cornell Aeronautical Laboratory, and visiting scientists on topics of interest in aeronautical science, especially in connection with new research.

7902. *ADVANCED SEMINAR IN AERONAUTICS*. Credit 2 hrs. Prereq., approval of the Director.

ENGINEERING PHYSICS

8051 and 8052. *PROJECT*. Terms 9 and 10. Credit 3 hrs. Fall and spring. Informal study under direction of a member of the University staff. The objective is to develop self-reliance and initiative, as well as to gain experience with methods of attack and with over-all planning, in the carrying out of a special problem related

to the student's field of interest. The choice of a problem is to be made by the student in consultation with members of the staff.

8090. *INFORMAL STUDY IN ENGINEERING PHYSICS*. Fall or spring. Laboratory or theoretical work in any branch of engineering physics under the direction of a member of the staff. Hours to be arranged.

8121. *CLASSICAL THERMODYNAMICS*. Credit 3 hrs. Fall. 3 Rec. Primarily for candidates for the degree of Bachelor of Engineering Physics. Introduction to the kinetic theory of gases and brief introduction to statistical mechanics. Application to physical and engineering problems.

8122. *CLASSICAL THERMODYNAMICS*. Credit 3 hrs. Spring. 3 Rec. Continuation of 8121.

8252. *SELECTED TOPICS IN PHYSICS OF ENGINEERING MATERIALS*. Credit 3 hrs. Fall term. Primarily for fifth year students in engineering physics; others with consent of instructor. Seminar-type discussion of a number of special topics in the field of engineering materials, such as plastic and rheological properties; dielectric and magnetic behavior; semi-conductors; radiation damage, etc. Emphasis is given to the interpretation of the phenomena in light of modern theories in physics of solids and liquids and their impact on the engineering applications; current literature is included in the assignments.

8311. *NUCLEAR AND REACTOR PHYSICS*. Credit 3 hrs. Fall. 3 Lect. Prereq., Physics 214 or 243. Nuclear particles, nuclear structure, nuclear reactions; characteristics of particle accelerators; properties of neutrons, interactions of neutrons with matter, nuclear fission; elementary reactor theory, types of reactors, reactor design problems; instruments for particle detection and reactor control.

8351. *NUCLEAR MEASUREMENTS LABORATORY*. Credit 2 hrs. Fall. Two 2½-hour afternoon periods. Experiments in alpha, beta, and gamma ray detection and absorption, in properties of various particle detectors and specialized electronic circuits used in particle counting and reactor control; in neutron detection and in interactions of neutrons with matter, especially moderation, diffusion, absorption, and scattering. Experiments are selected to meet individual needs of the student. Some stress is laid on independent work by the student.

8512. *ELECTRON MICROSCOPY*. Credit 3 hrs. Spring. Prereq., consent of the instructor. Lect. Lab. Hours to be arranged. Basic electron optics, image formation and interpretation, construction and operation of the electron microscope in physics, chemistry, and biology.

8517. *ELECTRON OPTICS AND ITS APPLICATIONS*. Credit 3 hrs. Fall. Prereq., Physics 225 (Physics 215 advised but not required). Electron beam formation, Gaussian dioptrics and aberrations of electron lenses, application including cathode ray tube, electron microscope, beta ray spectrometer, mass spectrometer.

GENERAL COURSES OF INSTRUCTION

Described in this section are certain courses prescribed for students in engineering, given in the College of Arts and Sciences, the College of Agriculture, or other divisions of the University as indicated below.

MILITARY TRAINING

The University requirement in military training (see p. 17 above and the *Announcement of the Independent Divisions and Departments*) may be satisfied:

(a) by four terms of satisfactory work in the Department of Military Science and Tactics (Military Science 11, 12, 21, and 22); or

(b) by four terms of satisfactory work in the Department of Air Science (Air Science 1A, 1B, 2A, 2B; or

(c) by four terms of satisfactory academic work in the Department of Naval Science (Naval Science 101, 102, 201, and 202). (According to their respective contractual agreements with the Navy, Regular and Contract NROTC students are committed to continue in the NROTC program for four years.)

Students who have had service in the armed forces may be exempt from the requirement in military training. For exemptions on other grounds, consult the *Announcement of the Independent Divisions and Departments*.

Advanced courses of two years in military science and tactics and air science are elective and may qualify students for appointments as Second Lieutenants in the Regular Army or Air Force, U.S. Army Reserve, or the U.S. Air Force Reserve.

The Department of Naval Science offers a four-year course of training which may qualify students for appointments as Ensigns in the Regular Navy or Naval Reserve or as Second Lieutenants in the Marine Corps or Marine Corps Reserve.

Academic credit of three hours a term may be earned in the advanced courses in military science and tactics and air science. This credit may be applied toward any of the free electives offered in the curricula of the College of Engineering. Students who complete the four-year course in naval science are given University credit for twenty-four hours of college work. At present, net credit toward degree requirements of the various schools of the College of Engineering is as follows: School of Mechanical Engineering, at least 9 hours; School of Electrical Engineering, 12 hours; School of Chemical and Metallurgical Engineering, 12 hours; School of Civil Engineering, 12 hours; Department of Engineering Physics, 6 hours.

Further details concerning the courses offered in military training may be obtained in the *Announcement of the Independent Divisions and Departments*.

PHYSICAL EDUCATION

The University requirement in physical education (see p. 18 above and the *Announcement of the Independent Divisions and Departments*) may be satisfied by four terms of work in the Department of Physical Education. For this purpose Physical Education 1, 2, 3, and 4 are available to men, and Physical Education 51, 52, 53, and 54, to women. Additional courses in physical education are described in the *Announcement of the Independent Divisions and Departments*.

ARCHITECTURE

REGIONAL AND CITY PLANNING

(In cooperation with the School of Civil Engineering)

400, 401. *HISTORY OF ARCHITECTURE*. Throughout the year. Credit 3 hrs. a term. A course primarily intended for students who are not architects but who are interested in a brief survey of the history of architecture and its relationship with parallel social, economic, and political trends. No experience in drawing or knowledge of structural elements is required. Either or both terms may be taken for credit.

700. *HISTORY OF CITY PLANNING*. Spring. Credit 3 hrs. Open to graduates and upperclassmen. The history of the planning of communities from ancient times to the present. Lectures, assigned reading, and examinations.

710. *PRINCIPLES OF CITY AND REGIONAL PLANNING*. Fall. Credit 3 hrs. Open to graduates and upperclassmen. A review of the basic influences in the

development of cities. A general view of the theory and accepted practice of city and regional planning, including a study of the social, economic, and legal phases. Lectures, assigned reading, and examinations.

711. *CITY PLANNING PRACTICE*. Spring. Credit 3 hrs. Prereq., Course 710. The procedures and techniques of gathering and analyzing data for municipal planning studies. The selection and integration of data for use in planning. Practical application of the theories of city planning. Office practice. Lectures, assigned readings, reports.

713. *HOUSING*. Spring. Credit 2 hrs. Registration limited. Prereq., Course 710. An introduction to the theory and standards of housing practice through analysis and comparison of various existing examples, considering the social, economic, and technical sides of the work. Lectures, assigned readings, and reports.

715. *PUBLIC PROBLEMS IN URBAN LAND USE*. Fall. Credit 2 hrs. Prereq., Course 710. Urban land policies, rent, taxation, and market factors.

717. *PLANNING AND ZONING LAW*. Spring. Credit 2 hrs. Prereq., Course 710. Technical and legal aspects of preparing and administering zoning ordinances. Examination of other legal problems in planning, including subdivision control, official map procedure, regulation of roadside development, and building and housing codes.

718. *CITY PLANNING DESIGN*. Fall. Credit 8 hrs. Limited to graduate students and, by permission, to seniors who may substitute it for Design 108. Students are assigned a series of design problems as a means of introduction to the basic principles of large-scale site planning. Lectures, discussions, and group and individual criticism.

720. *FIELD PROBLEM IN URBAN PLANNING*. Fall. Credit 8 hrs. Group study of an existing community and the preparation of a general plan for its development. Investigation of population trends, economic base, and regional influences. Land use analysis, and studies of traffic flow, recreation facilities, housing conditions, school and public building locations, automobile parking, public transportation and other elements of the community. Preparation of recommendations for carrying out the general plan. Lectures, discussions, field trips, preliminary and final reports.

CHEMISTRY

105-106. *GENERAL CHEMISTRY*. Throughout the year. Credit 3 hrs. a term. Chemistry 105 is prerequisite to Chemistry 106. For those students who will take more chemistry, it serves as a prerequisite to the more advanced courses. Open to those who have had or have not had high school chemistry. May be elected by students who do not intend to take more chemistry. The important chemical principles and facts will be covered, with considerable attention given to the quantitative aspects and to the techniques which are important for further work in chemistry.

111-112. *INTRODUCTORY INORGANIC CHEMISTRY*. Throughout the year. Credit 3 hrs. a term. Chemistry 111 is prerequisite to Chemistry 112. Chemistry 115-116 must be taken with Chemistry 111-112, except by consent of the instructor. Open to those students who have offered high school chemistry for entrance. Required of candidates for the degree of B.Ch.E. and recommended for candidates for the degree of A.B. with a major in chemistry. A study of the concepts and laws of inorganic chemistry and a systematic treatment of the common elements and their compounds based on atomic structure and the Periodic System.

113-114. *GENERAL CHEMISTRY AND INORGANIC QUALITATIVE ANALYSIS*. Throughout the year. Credit 4 hrs. a term. Chemistry 113 prerequisite to

Chemistry 114. Open to those who offered high school chemistry for entrance. Required of all students in the School of Chemical and Metallurgical Engineering. A general study of the laws and concepts of chemistry based upon the most common elements and application of the theory of chemical equilibrium to the properties and reactions of ions of the common elements and their separation and detection in solution.

115-116. *INTRODUCTORY INORGANIC LABORATORY AND QUALITATIVE ANALYSIS*. Throughout the year. Credit 3 hrs. a term. Chemistry 115 is prerequisite to Chemistry 116. Must be taken with Chemistry 111-112. The theories of chemistry are applied in a study of the preparation and properties of the common elements and their compounds and to the separation and detection of their ions.

224. *INTRODUCTORY QUANTITATIVE ANALYSIS*. Either term. Credit 4 hrs. Prereq., Chemistry 201, or 112 and 116. Required of candidates for the degrees of B.Ch.E. and A.B. with a major in chemistry. A study of the fundamental principles of gravimetric and volumetric analysis, with practice in stoichiometry, and the analyses of a variety of substances by volumetric, gravimetric, and colorimetric methods.

301. *INTRODUCTION TO ORGANIC CHEMISTRY*. Fall. Credit 2 hrs. Prereq., Chemistry 106. For students in engineering. A brief survey of the principal classes of organic compounds, their industrial sources, manufacture, and utilization.

307-308. *INTRODUCTORY ORGANIC CHEMISTRY*. Throughout the year. Credit 3 hrs. a term. Prereq., Chemistry 106 or 112. Qualitative analysis is desirable but not required. Chemistry 307 is prerequisite to Chemistry 308. Chemistry 311-312 must be taken with Chemistry 307-308. Required of candidates for the degrees of B.Ch.E. and A.B. with a major in chemistry. A systematic study of the more important compounds of carbon, their occurrence, methods of synthesis, relations, and uses.

311-312. *INTRODUCTORY ORGANIC LABORATORY*. Throughout the year. Credit 2 hrs. a term. Chemistry 311 is prerequisite to Chemistry 312. Must be taken with Chemistry 307-308. Required of candidates for the degrees of B.Ch.E. and A.B. with a major in chemistry. The student prepares typical compounds of carbon and familiarizes himself with the properties, reactions, and relations.

401. *INTRODUCTION TO PHYSICAL CHEMISTRY*. Fall term. Credit 3 hrs. Prereq., Chemistry 106, Mathematics 163, 183, or 193, and Physics 117. Primarily for students in electrical engineering. A brief survey of physical chemistry. Problems of interest to students in engineering will be discussed.

402. *INTRODUCTION TO PHYSICAL CHEMISTRY*. Spring. Credit 2 hrs. Prereq., Chemistry 106 or parallel courses, Mathematics 163, 183, or 193 and Physics 117. For students in civil and mechanical engineering. An additional recitation period will be arranged for engineering physics students and others who wish to obtain three hours credit for the course. A brief survey of physical chemistry. Problems of interest to students in engineering will be discussed.

403-404. *INTRODUCTORY PHYSICAL CHEMISTRY*. Throughout the year. Credit 3 hrs. a term. Prereq., Chemistry 224 and 308, Mathematics 163, 183, or 193, and Physics 118. Chemistry 403 is prerequisite to Chemistry 404. Required of candidates for the degree of B.Ch.E. A systematic treatment of the fundamental principles of physical chemistry. The laws of thermodynamics and of the kinetic theory are applied in a study of the properties of gases, liquids, and solids, thermochemistry, properties of solutions, and equilibrium in homogeneous and heterogeneous systems. Chemical kinetics and atomic and molecular structure are also studied.

411-412. *INTRODUCTORY PHYSICAL LABORATORY*. Throughout the year.

Credit 2 hrs. a term. Prereq. or parallel course, Chemistry 403-404 or 407-408. Chemistry 411 is prerequisite to Chemistry 412. Enrollment may be limited. Required of candidates for the degree of B.Ch.E. and A.B. with a major in chemistry. Quantitative experiments illustrating the principles of physical chemistry, and practice in performing typical physiochemical measurements. A part of the scheduled time is used for the discussion of experiments rather than for laboratory work.

ECONOMICS

103. *MODERN ECONOMIC SOCIETY*. Either term. Credit 3 hrs. Open to a limited number of freshmen. A survey of the existing economic order, its more salient and basic characteristics, and its operations.

203. *MONEY AND BANKING*. Fall. Credit 3 hrs. Prereq., Economics 104. A study of our currency system and banking processes for the primary purpose of training the student to determine the influence of monetary factors in economic problems.

EDUCATION

7. *READING IMPROVEMENT PROGRAM*. Fall or spring term. Noncredit. Prereq., all students are required to take the Cooperative Reading Test at times to be announced. Lect. and discussion: M W 8, 9, 10, 11, 1, 2, or T Th 8, 9, 10, 11, 1, 2. Lab.: two half-hour periods a week to be arranged. Fall program is reserved for selected freshmen. Spring is open to all registered students. Enrollment limited. Designed to increase efficiency in reading rate and comprehension. Principles and techniques of good reading are explained, demonstrated, and practiced in class. The laboratory is equipped to provide an opportunity to practice good reading habits under controlled conditions.

ENGLISH

111-112. *INTRODUCTORY COURSE IN READING AND WRITING*. Throughout the year. Credit 3 hrs. a term. Open to freshmen, English 111 is prerequisite to 112. The aim of this course is to increase the student's ability to communicate his own thought and to understand the thought of others.

ENGLISH FOR FOREIGNERS

The following two courses are offered by the Division of Modern Languages. Foreign students should consult a member of that division in Morrill Hall 108.

102. *ENGLISH FOR FOREIGNERS*. Fall. Credit 6 hrs. Prereq., placement by the instructor. Hours to be arranged.

211. *ENGLISH FOR FOREIGNERS*. Fall. Credit 6 hrs. Prereq., a satisfactory proficiency examination. Hours to be arranged.

GEOLOGY

113. *ENGINEERING GEOLOGY*. Either term. Credit 3 hrs. Students who have had Geology 101-102 or 115 may take 113 for one hour credit. To provide a geologic background so that the engineer will be competent to adapt his work to conform with the limitations imposed by geologic conditions.

712. *METALLURGICAL RAW MATERIALS*. Fall. Credit 3 hrs. For second year students in metallurgical engineering. The properties, occurrence, associations, distribution, and economic aspects of the commercially important ore, refractory, and fluxing materials that enter metallurgical operations.

HISTORY

165-166. *SCIENCE IN WESTERN CIVILIZATION*. Throughout the year. Credit 3 hrs. a term. A survey of the development of science in its relation to the main currents of European and American civilization from classical antiquity to the present day.

INDUSTRIAL AND LABOR RELATIONS

293. *SURVEY OF INDUSTRIAL AND LABOR RELATIONS*. Either term. Credit 3 hrs. A survey for students not in the School of Industrial & Labor Relations. An analysis of the major problems in industrial and labor relations: labor union history, organization, and operation; labor market analysis and employment practices; industrial and labor legislation and social security; personnel management and human relations in industry; collective bargaining; mediation and arbitration; the rights and responsibilities of employers and employees; the major governmental agencies concerned with industrial and labor relations.

MATHEMATICS

161. *ANALYTIC GEOMETRY AND CALCULUS*. Either term. Credit 3 hrs. Prereq., trigonometry and intermediate algebra. Hours to be arranged. Plane analytic geometry through conics. Differentiation and integration of polynomials with applications to rates, maxima, volumes, pressures, etc.

Courses 161-162-163 represent a standard three-term calculus sequence, presenting the main ideas and techniques of the calculus and analytic geometry; the material is so arranged that the first two terms (161-162) provide a reasonably complete introduction to the subject. This sequence of courses is not intended as preparatory to more advanced courses in mathematics, although admission to such courses can be obtained following this sequence by special permission. (For students who took the 161-162-163 sequence when it was the only one offered, this will continue to serve as the prerequisite to advanced work.) Students majoring in mathematics or in those physical sciences where mathematics is extensively used or who have special mathematical competence should elect the 181-182-183 sequence instead.

162. *ANALYTIC GEOMETRY AND CALCULUS*. Either term. Credit 3 hrs. Prereq., Mathematics 161. Hours to be arranged. Differentiation and integration of algebraic, trigonometric, logarithmic, and exponential functions, with applications. Related topics, including polar coordinates, parametric equations, and vectors.

163. *ANALYTIC GEOMETRY AND CALCULUS*. Either term. Credit 3 hrs. Prereq., Mathematics 162. Hours to be arranged. Infinite series, solid analytic geometry, partial derivatives, and multiple integrals.

181. *ANALYTIC GEOMETRY AND CALCULUS*. Either term. Credit 3 hrs. Prereq., trigonometry and intermediate algebra. Hours to be arranged. The range of topics will be similar to that of Mathematics 161, but each will be covered more intensively. Intended primarily for students of superior mathematical ability. (See remarks under Mathematics 161 above.)

182. *ANALYTIC GEOMETRY AND CALCULUS*. Either term. Credit 3 hrs. Prereq., Mathematics 181. Hours to be arranged.
Topics similar to those of Mathematics 162.

183. *ANALYTIC GEOMETRY AND CALCULUS*. Either term. Credit 3 hrs. Prereq., Mathematics 182. Hours to be arranged.
Topics similar to those of Mathematics 163.

201. *ELEMENTARY DIFFERENTIAL EQUATIONS*. Either term. Credit 3 hrs. Prereq., Mathematics 163. Solution of ordinary differential equations by analytic and numerical methods.

607. *APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS*. Spring term. Credit 3 hrs. Prereq., Mathematics 163. Primarily for undergraduates. Complex numbers, linear differential equations, linear algebra and matrices, solution of algebraic and transcendental equations, Fourier series.

611-612. *HIGHER CALCULUS*. Throughout the year. Credit 3 hrs. a term. Prereq., Mathematics 201. First term prerequisite to second. Partial differentiation, multiple and line integrals, Fourier series, partial differential equations, vector analysis, complex variables, calculus of variations, Laplace transforms. Emphasis is placed on a wide range of formal applications of the calculus, rather than on the logical development. The second term will be accepted as prerequisite to complex variables.

613-614. *METHODS OF APPLIED MATHEMATICS*. Throughout the year. Credit 3 hrs. a term. Prereq., Mathematics 183 and 201. First term prerequisite to second. Students not majoring in engineering physics must obtain consent of the teacher. This constitutes the first year of a two-year sequence and should be taken only by students who intend to cover the remaining topics either by taking the continuation 615-616 or by taking other courses such as 531. Courses 613-616 cover essentially the same ground as 611, 612, 621, 622, but in a more coordinated fashion. Topics to be covered are vector analysis, calculus of functions of several variables, infinite series. Fourier series and integrals, Laplace transforms, complex numbers, matrix theory.

621-622. *MATHEMATICAL METHODS IN PHYSICS*. Throughout the year. Credit 4 hrs. a term. Prereq., a good knowledge of the techniques of the calculus, such as given by 611-612, and at least two years of general physics. First term prerequisite to second. For mature students who wish to acquire a wide background of mathematical techniques in one year. Lectures and problem work designed to give the students a working knowledge of the principal mathematical methods used in advanced physics. Topics taken up include infinite series, Fourier series and integrals, Laplace transforms, complex variables, calculus of variations, matrices, integral equations, and eigenvalue problems.

PHYSICS

113. *ELECTRICITY AND MAGNETISM*. Fall. Credit 2 hrs. Prereq., Physics 115, 116, calculus or simultaneous registration in Mathematics 163. One recitation and one discussion period a week to be arranged and one laboratory period of $2\frac{1}{2}$ hours on alternate weeks to be arranged. For students of civil engineering only. Survey of the fundamental laws of electric and magnetic fields, electric circuits, induced emfs, inductance, and capacitance. The laboratory experiments are illustrative of the topics mentioned.

114. *PHYSICAL OPTICS AND ATOMIC PHYSICS*. Spring. Credit 2 hrs. Prereq., Physics 113. One recitation and one discussion period a week to be arranged, and one laboratory period of $2\frac{1}{2}$ hours in alternate weeks to be arranged. For students of civil engineering only. Survey of electromagnetic waves and their applications to optical phenomena. Survey of selected topics in atomic and nuclear physics, electronic emission, and photoelectricity. The laboratory experiments are illustrative of the topics mentioned.

Note: Physics 115, 116, 117, and 118 form a sequence in a two-year continuous course in General Physics required of all students of engineering who are candidates

for the degree of B.Ch.E., B.E.E., B.Eng.Phys., and B.M.E. Physics 115, 116, 113, and 114 constitute the corresponding sequence for candidates for the degree B.C.E. Demonstrations, theory, experiments, and problem drill. One lecture, two recitations, and one laboratory period a week, as assigned. Consult instructor in charge for available recitation and laboratory periods.

115. *MECHANICS*. Fall term. Credit 3 hrs. Prerequisite, calculus or simultaneous registration in Mathematics 161 or 181. Entrance Physics is desirable but not required. Statics, kinematics, dynamics, energetics, elasticity, mechanics of fluids. The laboratory work consists of measurements related to the above topics.

116. *HEAT, SOUND, AND GEOMETRICAL OPTICS*. Spring. Credit 3 hrs. Prereq., Physics 115, calculus, or simultaneous registration in Mathematics 162, 182, or 192. Temperature, calorimetry, change of state, heat transfer, thermal properties of matter, elementary thermodynamics, wave motion, vibrating bodies, acoustical phenomena, geometrical optics, reflection, refraction, mirrors, and lenses. The laboratory work consists of measurements related to the above topics.

117. *ELECTRICITY AND MAGNETISM*. Fall. Credit 3 hrs. Prereq., Physics 115, 116, calculus, or simultaneous registration in Mathematics 163. Introductory study of the fundamental laws of electric and magnetic fields and their applications to elementary circuit problems. Electrostatic fields and potential; steady currents, induced emfs, inductance, dielectrics, capacitance, and simple transients. The laboratory work consists of basic measurements in direct current circuits.

118. *PHYSICAL OPTICS AND ATOMIC PHYSICS*. Spring. Credit 3 hrs. Prereq., Physics 117. Properties of electromagnetic waves and their application to optical phenomena; interference, diffraction, and polarization. Selected topics in atomic and nuclear physics; spectra, electron emission processes, radioactivity, and nuclear reactions. The laboratory work consists of basic experiments in physical electronics and physical optics.

208. *PHYSICAL MECHANICS AND PROPERTIES OF MATTER*. Spring. Credit 3 hrs. Prereq., Physics 115 and Mathematics 161 and 162. Primarily for candidates for the degree of Bachelor of Engineering Physics. Elements of kinematics; Newton's law; conservation laws and application to selected problems; hydrostatics; elementary fluid dynamics.

210. *ADVANCED LABORATORY*. Either term. Credit 3 hrs. a term. Prereq., Physics 207 and 209 or the equivalent. Required for physics majors. About sixty different experiments are available among the subjects of mechanics, acoustics, optics, spectroscopy, electrical circuits, electronics and ionics, heat, X-rays, crystal structure, solid state, cosmic rays, and nuclear physics. During the term the student is expected to perform five to ten experiments, selected to meet his individual needs. Stress is laid on independent work on the part of the student.

214. *ATOM, NUCLEAR, AND ELECTRON PHYSICS*. Spring. Credit 3 hrs. 2 Lect. and 1 Rec. Prereq., Physics 118 and Mathematics 607 or the equivalents. Primarily for students in electrical engineering. Two lectures and one recitation hours to be arranged. Elements of nuclear and atomic structure, fundamentals of quantum theory, basic kinetic theory of atoms and electrons; electronic processes with special reference to the electrical properties of metals, semiconductors, and insulators and general electron emission processes; elements of nuclear processes.

225. *ELECTRICITY AND MAGNETISM*. Either term. Credit 3 hrs. Prereq., Physics 117 or 207 and 209 or their equivalent (209 may be taken concurrently). Electrostatic and electromagnetic fields, polarization of dielectrics and magnetic media, displacement current, plane electromagnetic waves, the Poynting vector.

235. *ELECTRICITY AND MAGNETISM*. Spring. Credit 3 hrs. Prereq., Physics 225 and differential equations. Circuit theory from the standpoint of electromagnetic fields. Validity and limitation of circuit concepts. Steady and alternating currents in circuits and networks, distributed parameters, introductory high-frequency topics, high-energy machines.

242. *ANALYTICAL MECHANICS*. Spring. Credit 3 hrs. Prereq., Physics 207 and Mathematics 201, or their equivalents. Analytical mechanics of material particles, systems of particles and rigid bodies; planetary motion, stability of orbits; collisions; Euler's equations, gyroscopic motion; Lagrange's equations, relativistic mechanics.

243-244. *ATOMIC, MOLECULAR, AND NUCLEAR PHYSICS*. Throughout the year. Credit 3 hrs. a term. Prereq., Physics 225 or consent of instructor. The fundamental particles of physics, statistical physics, the concepts of quantum mechanics, atomic structure and spectra, the periodic table, molecular structure and the chemical bond, properties of nuclei, nuclear reactions, interaction of radiation with nuclei, behavior of high-energy particles, and cosmic rays.

254. *ELECTRONIC PROPERTIES OF SOLIDS AND LIQUIDS*. Spring term. Credit 3 hrs. Prereq., Physics 243. A semiquantitative introduction to the concepts of modern solid state physics, covering lattice structure, lattice defects, lattice vibrations, cohesive energy, elastic and anelastic properties, electron theory of metals and semiconductors, dielectric and magnetic properties.

258. *MECHANICS OF CONTINUA*. Spring term. Credit 3 hrs. Prereq., partial differential equations or consent of instructor. Hours to be arranged. Stress and strain tensors; fundamental equations of motion in continuous media; generalized equations of state; applications to special topics in elasticity, wave propagation, vibration, flow of ideal and viscous fluids, etc.

475. *THEORETICAL MECHANICS*. Fall. Credit 3 hrs. Prereq., Physics 242 or its equivalent.

PSYCHOLOGY

101. *INTRODUCTION TO PSYCHOLOGY*. Either term. Credit 3 hrs. Open to freshmen. Two lectures plus either a third lecture or a recitation section each week, as announced. An introduction to the scientific study of behavior and experience, covering such topics as perception, motivation, emotion, learning, thinking, personality, and individual differences. This course is prerequisite to further work in the Department.

PUBLIC SPEAKING

101. *PUBLIC SPEAKING*. Either term. Credit 3 hrs. Not open to freshmen. Designed to help the student communicate his ideas and convictions effectively in oral discourse. Study of basic principles of expository and persuasive speaking, with emphasis on finding, evaluating, and organizing materials, and on simplicity and directness in style and delivery. Practice in preparing and delivering speeches of various types on current issues and in chairmanship; study of examples; conferences. The services of the Speech Clinic are available to those students who need remedial exercises. Foreign students and others whose pronunciation of English falls below the normal standard, and students with special vocal problems, are advised to confer with Mr. Thomas before registering.

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